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Micro-Level Landslide Hazard Zonation of Saitual Town, Mizoram, India Using Remote Sensing and GIS Techniques

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Abstract

Landslide is the major geo-environmental problem in the state of Mizoram. In the present study, landslide hazard zonation (LHZ) of Saitual town, Aizawl disrict was carried out using Remote Sensing and Geographic Information System (GIS) techniques. Five thematic layers viz., slope morphometry, geological structures like faults and lineaments, lithology, relative relief and land use / land cover were first generated. The thematic layers were ranked and weightage rating system was used for the different classes within these causative factors 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. Summation of these attribute values were then multiplied by the corresponding rank values to yield the different zones of landslide hazard. It was observed that complex tectonic frameworks, soft lithology, high degree of slope angle, high local relief, high intensity rainfall and anthropogenic acitvities are the important factors that induces landslide in the area. Increase in human population and the collateral activities can gradually induce the potential risk from landslides. The micro level landslide hazard zonation map generated could be utilized as a reliable database for mitigation measures and planning for secured growth of the town.

Keywords: GIS, Landslide Hazard Zonation, Remote Sensing, Saitual town

Introduction

Landslide is one of the main geo-environmental hazards causing loss of lives, and damage to roads, bridges and houses (Sarkar and Kanungo, 2004; Gurugnanam et al., 2012). Rapid growth of population in urban areas lead to high vulnerability of human lives and properties in terms of natural hazards. Therefore, landslides can become disaster when they occur in such human habitations (Chandel et al., 2011) and human settlements can become highly vulnerable to natural disaters when they are located on hill slopes (Rawat et al., 2010). The geology of Mizoram comprises N-S trending anticlinal strike ridges with steep slopes, narrow intervening synclinal valleys, dissected ridges with deep gorges, spurs and keels. Faulting in many areas has produced steep fault scarps (GSI, 2011).

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

In the field of geo-sciences, Remote Sensing and GIS have extensive applications (Jeganathan and Chauniyal, 2002), and many researchers have attempted landslide hazard zonation using these techniques (Dinachandra Singh et al., 2010). Remote Sensing and GIS techniques had been used to carried 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 lower resolution satellite data, viz., IRS LISS III and PAN data had also been done, and it was concluded that these data can be used effectively for generating Landslide Hazard Zonation map (Lallianthanga and Laltanpuia, 2007). Remote Sensing and GIS techniques have been proved to be of immense value world-over in landslide hazard zonation, and this had been validated in the study conducted for Aizawl city (MIRSAC, 2007). The same techniques had also been successfully applied in Landslide Hazard Zonation studies for Serchhip town (Lallianthanga and Lalbiakmawia, 2013), Mamit town of Mizoram (Lallianthanga et al., 2013) and for the entire Aizawl district (Lallianthanga and Lalbiakmawia, 2013). The present study utilizes Quick bird and IRS-P5 Carosat-I data to map the different landslide hazard zones of Saitual town to determine the utility of Remote Sensing and GIS, to create database for mitigation measures of landslides and also to identify suitable areas for future development within the township.

Study Area

Saitual town is located in the north-eastern part of Mizoram, in the north-east corner of India. With a total area of 12.34 sq km. the town is geographically located between 92o 56′ 30" to 93o 59′ 11" E longitudes and 23o 38′ 23" to 23o 44′ 45" N latitudes. It falls under Survey of India topo sheet No. 84A/14. 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 entire Aizawl district is under the direct influence of south west monsoon, with average annual rainfall of 2155.3 mm (MIRSAC 2012).

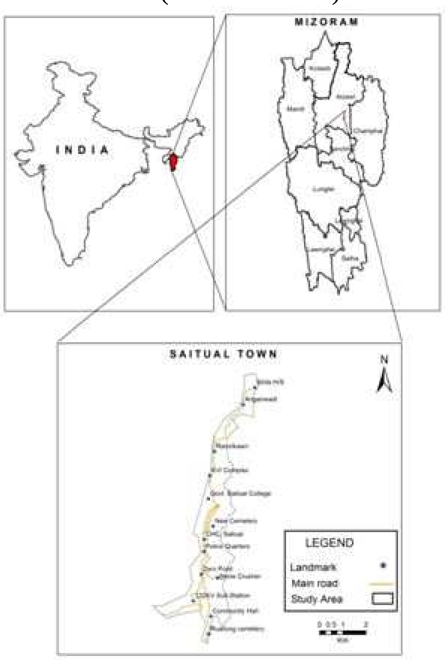

Figure 1: Location map of study area

Materials and Methods

Data used

Indian Remote Sensing Satellite (IRS-P5) stereo-paired Cartosat-I data having spatial resolution of 2.5 m and Quick bird data having spatial resolution of 0.8 m were used as the main data. SOI topographical maps and various ancillary data were also referred to.

Thematic layers

There are several causative factors that induced landslide (Bijukchhen *et al.*, 2009). Selection of these factors and preparation of thematic data layers are highly crucial for landslide susceptibility mapping (Sarkar and Kanungo, 2004). Integration of multi-sources of information signify a major goal to achieve more reasonable results in the assessment of many environmental issues (Archana and Kausik, 2013). In the present study, five important thematic layers were prepared from satellite data and field work. These layers were then utilised for Landslide Hazard Zonation. The different layers are as follows-

Land use / Land cover

As land use / land cover controls the rate of weathering and erosion, it is one of the most important factor in Landslide Hazard Zonation. The study area was divided into five classes, viz., Heavy Vegetation, Light Vegetation, Scrubland, Built-up and barren land. Areas with dense vegetation cover were considered less prone to the occurrence of landslides (Mohammad Onargh *et al.*, 2012), hence, Heavy Vegetation class was assigned low weightage value. Built-up areas were more prone to landslide than all the other classes (Pandey *et al.*, 2008) and were given high weightage. The statistics of land use / land cover is given in Table 1 and the map is shown in Fig. 2.

Table No. 1: Land use/land cover statistics of Saitual town

Land use Class	Area (Sq.Km.)	Percentage
Heavy Vegetation	4.76	38.57
Light Vegetation	3.62	29.32
Scrubland	2.82	22.83
Built up	1.06	8.58
Barren land	0.08	0.70
Total	**12.34**	**100**

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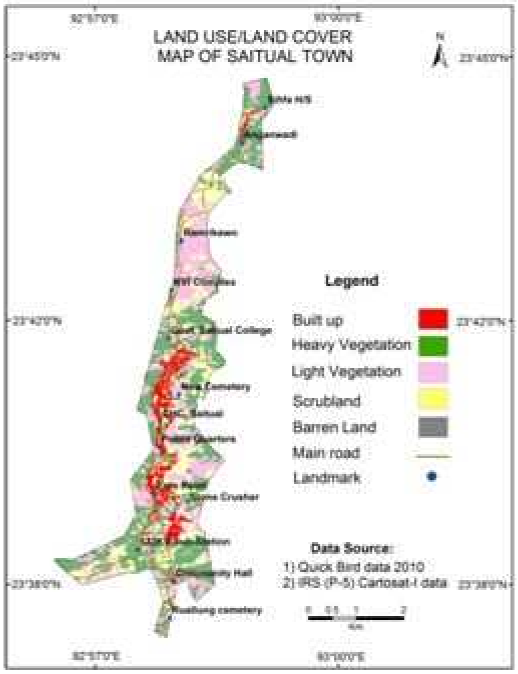

Figure 2: Land use / Land cover map of Saitual town

Slope

Landslides are more widespread in the steep slope areas than in moderate and low slope areas (Sharma *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 using the IRS-P5 stereo-paired Cartosat-I data and Digital Elevation Model (DEM) in a GIS environment. The slopes of the area are represented in terms of degrees, and are conveniently divided into eight slope facets, viz., 0-15, 15-25, 25-30, 35-40, 40-45 and above 45 degrees. Weightage values are assigned in accordance with the steepness of the slope. The slope statistics of the area is given in Ta ble 2 and slope map is shown in Fig. 3.

Table No. 2: Slope statistics of of Saitual town

Degree of Slope	Area (Sq.Km.)	Percentage
0-15	3.19	25.85
15-25	4.70	38.09
25-30	1.68	13.61
30-35	1.17	9.48
35-40	0.76	6.16
40-45	0.49	3.97
>45	0.35	2.84
Total	**12.34**	**100.00**

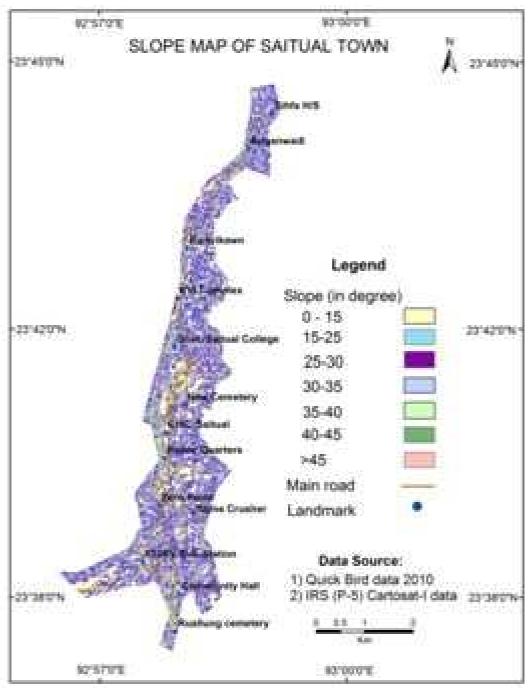

Figure 3: Slope map of Saitual town

Relative relief

Relative relief is an important factor in landslide hazard zonation and plays a decisive role in the vulnerability of settlements, transport network and land (Chandel *et al.*, 2011). The study area possesses high relative or local relief and was divided into High,

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Moderate and Low classes with elevation ranging from more than 1200m, 1000-1200m and less than 1000m from msl respectively. High elevated areas are more susceptible to landslide than areas with lower elevation (Lee *et al.*, 2004). Following this pattern, weightage values are given to each of the relative relief classes. The area coverage of different relative relief classes is given in Table 3 and relative relief map of the study area is shown in Fig. 4.

Table No. 3: Relative relief statistics of Saitual town

Relative Relief Classes	Area (Sq.Km.)	Percentage
High	0.69	5.60
Medium	7.19	58.26
Low	4.46	36.15
Total	**12.34**	**100**

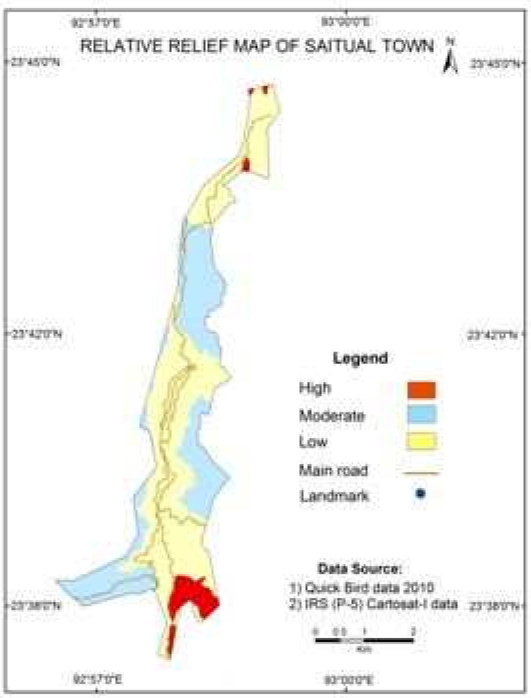

Figure 4: Relative relief map of Saitual town

Lithology

Lithology is one of the most significant parameters for landslide hazard zonation (Sharma *et al.*, 2011). The geology of Mizoram consisted of great flysch facies of rocks comprising monotonous sequences of shale and sandstone (La Touche, 1891). The study area lies over Bhuban sub-group of Surma Group of Tertiary age (GSI, 2011) and this formation was further sub-divided into Lower, Middle and Upper formations. Middle Bhuban which consist of mainly argillaceous rock is exposed within the study area. Four litho-units have been established for the study area purely based on the exposed rock types. These are named as Shale-siltstone unit, Shale-sandstone unit, Sandstone-shale unit and Crumpled shale unit. Lithological units comprising shale and siltstone are more susceptible to landslide than the hard and compact sandstone - shale units. Crumples shale is the most susceptible unit to landslide amongst the rock types in the area. In accordance with this, weightage values are assigned for analysis. The statistics of lithological unit is given in Table 4 and the geological map showing the lithology of the area is shown in Fig. 5.

Geological Structure

Geological structures like faults, fractures, joints, etc. can be observed and measured using remote sensing data (Kanungo *et al.*, 1995). Structure and lithology are among the most important parameters for Landslide Hazard Zonation (Saha *et al.*, 2002) and it was observed that the rocks exposed within the study area are 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 showing the geological structure is given in Fig. 5.

Table No. 4: Lithological statistics of Saitual town

Rock Types	Area (Sq. Km.)	Percentage
Shale & Siltstone	6.39	51.79
Shale &Sandstone	3.93	31.87
Sandstone & Shale	1.94	15.66
Crumpled shale	0.08	0.68
Grand Total	**20.83**	**100**

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Figure 5: Geological Map of Saitual town

Data Analysis

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 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 susceptibility. Weightage value is assigned for each class based on their susceptibility 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. All the thematic layers were integrated and analysed in a GIS environment using ARCINFO (9.3 version) 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 in Table 5.

Table No.5 : Ratings for Parameters on a scale of 1-10

Parameter	Rank (in percent)	Category	Weight
Lithology	25	Sandstone & Shale	4
		Shale & Siltstone	8
		Crumpled Shale	10
		Shale & Sandstone	6
Land Use / Land Cover	15	Heavy Vegetation	3
		Light Vegetation	5
		Scrubland	6
		Built-up	8
		Barren land	5
Slope Morphometry (in degrees)	35	0 - 15	1
		15-25	3
		25-30	4
		30-35	5
		35-40	6
		40-45	7
		>45	8
Structure (Faults and Lineaments)	15	Length of Buffer distance on either side	8
Relative relief	10	High	4
		Medium	3
		Low	2

Results and Discussion

Combining all the controlling parameters by giving different weightage value for all the themes, the final LHZ map is prepared and categorised into 'Very High', 'High', 'Moderate', 'Low' and 'Very Low' hazard zones. The output map is generated on a scale of 1: 5,000. Various hazard classes are described below:

Very High Hazard Zone

This zone consist of steep slopes with unconsolidated materials which are located near faults and tectonically weak zones. Therefore, this zone is highly unstable and is at a constant threat from landslides. The very high hazard zone is more prevalent in the northern and central part of the town. This zone constitutes an area of about 0.22 sq. km and forms 1.78% of the total study area. Since the Very High Hazard Zone is considered highly susceptible to landslides, it is recommended that no human induced activity be undertaken in this zone. Such areas have to be entirely avoided for settlement or other developmental purposes.

High Hazard Zone

It covers the area of steep slopes which when disturbed are prone to landslides. It also includes areas where the probability of sliding debris is high due to weathered rock and soil debris. 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. Several lineaments, fractured zones and fault planes also traverse the high

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hazard zone. Areas which experience constant erosion by streams also fall under this class. It is commonly found to surround the Very High Hazard Zone. This zone occupies 0.41 sq. km which is 3.32% of the total area. Since, the High Hazard Zone is geologically unstable, allocation and execution of major housing structures and other projects within the vicinity of this zone should be discouraged. Besides, it is also recommended that proper canalization of the streams and improvement of the drainage system be undertaken along the streams where toe-erosional activities are maximum.

Moderate Hazard Zone

This zone is generally considered stable as long as its present status is maintained. It comprises areas moderate slope angle and relatively compact and hard rocks. The Moderate Hazard Zone is well distributed within the study area and several parts of the human settlement also come under this zone. Seismic activity and continuous heavy rainfall may also reduce its stability. As such, it is important not to disturb the natural drainage, and at the same time, slope alteration should also be avoided as far as possible. It is recommended that human activity that can destabilize the slope and trigger landslides should not be undertaken within this zone. Although this zone comprises areas which are stable in the present condition, future land use activity has to be properly planned so as to maintain its present status. This zone covers 4.97 sq. km. which is 40.28 % of the total study area.

Low Hazard Zone

This zone comprises of areas where the controlling factors are unlikely to have adverse pressure on the slope stability. The slope angles are generally low, about 30 degrees or below. Therefore, all the areas having gentle slope degrees with light vegetation or scrubland fall under this zone. As far as the risk factor is concerned, no evidence of instability is observed within this zone, and mass movement is not expected unless major site changes occur. Therefore, this zone is suitable for carrying out developmental schemes. It spreads over an area of about 6.17 sq. km. and occupies 50.00% of the total study area.

Very Low Hazard Zone

This zone generally includes areas with low slope angles with thick vegetation. 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. This zone extends over an area of about 0.57 sq. km. and forms 4.62 % of the total area.

The area statistics of the landslide zones are given in Table 6 and the landslide hazard zonation map is shown in Fig. 6.

Table No. 6: LHZ statistics of Saitual town

LHZ Code	Hazard Class	Area (Sq.km)	Percentage
1	Very High	0.22	1.78
2	High	0.41	3.32
3	Moderate	4.97	40.28
4	Low	6.17	50.00
5	Very Low	0.57	4.62
TOTAL		12.34	100.00

Figure 6: Landslide Hazard Zonation map of Saitual town

Conclusion

The present study proved that the physical factors like land use/ land cover, lithology, slope, geological structure and relative relief are directly linked with landslide hazard. Fortunately, due to low slope angles and limited human activities, large part of the study area falls under Low to Very low landslide hazard zones at the moment. However, increase in human population which may results in haphazard settlement and uncontrolled expansion of roads can induce the occurence of landslides. Therefore, the landslide hazard map prepared through the present study can be utilised for identifying the critical areas for implementing suitable mitigation measures as well as for selecting sites further expansion of the town. It is also significant to bear in mind that though very high and high hazard zones are confined in small areas, the other parts of the township that fall within moderate hazard zone may also become highly unstable if unplanned anthopogenic activities are continued without considering the geo-environmental condition.

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