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Research Article

LANDSLIDE HAZARD ZONATION OF MAMIT TOWN, MIZORAM, INDIA USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT
Landslide is the main cause of massive damage in tectonically active hilly terrain of the Himalayan region including the state of Mizoram. It can be disastrous causing destruction to life and property, and may also lead to large scale landscape transformations. The main causes of landslide can be attributed to unplanned human activities in the areas that are liable to its occurrence. Such areas are commonly found within the township and cities where various infrastructural amenities and constructions are carried out without proper awareness of site safety and feasibility. Mamit is a small town, and is the headquarters of the recently formed Mamit district. In the present context, the landslide hazards areas are confined in few places due to the stable environment and limited anthropogenic activities within the town. However, the geo-environmental condition can become worst in this growing town unless proper planning for developmental activities is done. Therefore, the present study was taken up to investigate the Landslide Hazard Zonation (LHZ) of Mamit town using high resolution satellite data. Using Remote Sensing and Geographic Information System (GIS) techniques, thematic layers like slope morphometry, geological structures like faults and lineaments, lithology, relative relief and land use / land cover were generated. The weightage rating system based on relative importance of various causative factors was used for different classes of thematic layers. The classes were assigned the corresponding rating value as attribute information in the GIS environment. Each class within a thematic layer was assigned an ordinal rating from 0 to 10. Summation of these attribute value were then multiplied by the corresponding weights to yield the different zones of landslide hazard. A landslide hazard zonation map was prepared showing five different zones ranging from very low hazard zone to very high hazard zone which is essential for carrying out quicker and safer mitigation programmes, as well as for future developmental planning.

Key Words: *GIS, Landslide Hazard Zonation, Mitigation, Remote Sensing*

INTRODUCTION
Landslide activities are closely associated with the tectonically active Himalayan regions, and are the most common natural hazards which lead to damage in the road sector and residential areas in the hilly terrains (Gurugnanam *et al.*, 2012). They are just a hazard when they occur in an uninhabited place. However, they turn into disasters when they occur in the vicinity of human habitation (Chandel *et al.*, 2011). Increase in population and rapid urbanization has led to expansion of construction activities in hilly terrain and has heightened the frequency of landslides to dramatic proportions in recent decades (Onargh *et al.*, 2012). The topography of Mizoram is geologically immature. There are N-S trending mostly anticlinal strike ridges with steep slopes and narrow intervening synclinal valleys with series of parallel hummocks or topographic highs. The other landforms of the state are dissected ridges with deep gorges, spurs, keels, etc. Faulting in many areas has produced steep fault scarps (GSI, 2011). Thus, Mizoram, being a hilly terrain is extremely prone to landslides.
During the monsoon season of 2010, Bazar veng locality of Mamit town was severely affected by subsidence and landslides endangering the lives and properties of hundreds of people. About 50 families were evacuated and about 43 houses dismantled. This incident makes it essential to generate a Landslide Hazard Zonation of this area.

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Studies on landslides in Mizoram are meager. The earliest work on geology of Mizoram was done in 1891 and was reported that the area consisted of great flysch facies of rocks comprising monotonous sequences of shale and sandstone (La Touche, 1891). Few attempts were made to study landslide within the state. These include geotechnical appraisal of Bawngkawn landslide (1994), examining the causes of the slope failure and suggestions for remedial measures (Tiwari and Kumar, 1996). The possible causes of South Hlimen landslide (1992) which claimed the lives of almost 100 people were also critically examined and suggestions for mitigation measures were made (Tiwari and Kumar, 1997). An in-depth study of Vaivakawn landslide with geotechnical laboratory testing of the slide materials had also been carried out and suggestions for remedial measures were made (Choubey, 1992). The above three locations where landslide studies were carried out are within Aizawl city area. Micro-level Landslide Hazard Zonation Mapping was carried out in Serchhip town in which the study area was divided into Low Hazard Zone, Moderate Hazard Zone, High Hazard Zone and Very High Hazard Zone. Suggestions for expansion of the townships were also given (Ghosh and Singh, 2001). Geo-data based Total Estimated Landslide Hazard Zonation at the southern part of the state was also carried out and it was concluded that landslide hazard zonation map is of fundamental importance during planning and implementation of developmental work in a hilly state like Mizoram (Lalnuntluanga, 1999).

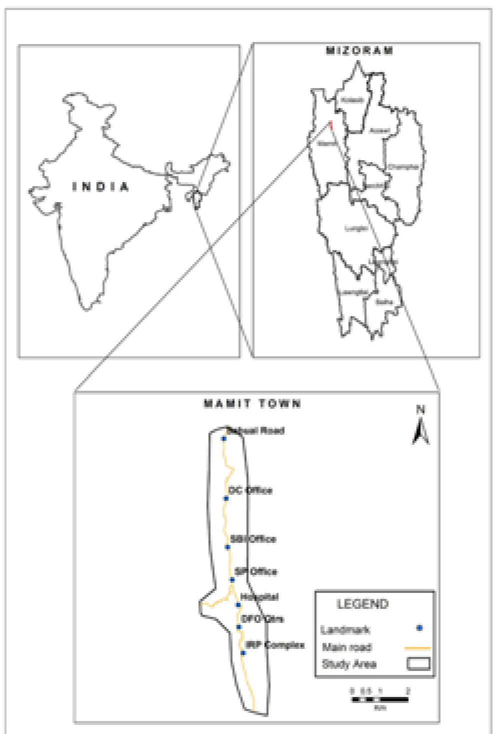

Figure 1: Location map of study area

Several researchers have attempted landslide hazard zonation using Remote Sensing and GIS techniques (Dinachandra Singh *et al.*, 2010). Using the said technique, Landslide Hazard Zonation of Uttaranchal and Himachal Pradesh States had been carried out successfully by the then 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 worldover in hazard zonation, and this has been validated in the study conducted for Aizawl city (MIRSAC, 2001). The same technique has also been successfully applied in Landslide Hazard Zonation studies for Serchhip town of Mizoram (Lallianthanga and Lalbiakmawia, 2013). Keeping all these in mind, the present study utilizes high resolution satellite data, viz., Quick bird and IRS-P5 Carosat-I data to map the different landslide hazard zones of Mamit town for undertaking mitigation measures and to identify suitable areas for future development within the township.

Study Area

The study area covers the entire Mamit Township, the administrative headquarters of Mamit district which is having a total area of 13.66 sq km. It is linked by State Highway with Aizawl, the state capital of Mizoram at a distance of 103 km. Mamit town is geographically located at the western part of Mizoram between 92^{o} 29′ 00" to 92^{o} 30′ 30" E longitudes and 23^{o} 52′ 30" to 23^{o} 58′ 00" N latitudes. Location map of the study area is shown in Fig. 1. It falls under Survey of India topo sheet No.84A/5 and 84A/9. The climate of the study area ranges from moist tropical to moist sub-tropical. The entire district is under the direct influence of south west monsoon, with average annual rainfall of 3067 mm (MIRSAC 2012).

MATERIALS AND METHODS

Data used

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

Thematic layers

Five thematic layers prepared from satellite data and field work were utilised for this study. They are as follows-

Land use / Land cover: Land use / land cover plays an important role in Landslide Hazard Zonation as it controls the rate of weathering and erosion of the underlying rock formations. The study area was divided into five classes, viz., Heavy Vegetation, Light Vegetation, Scrubland, Built-up and Barren land. The areas covered by heavy vegetation were found to be least susceptible to landslide; hence Heavy Vegetation class was assigned low weightage value. Due to human interference, Built-up areas were more prone to landslide than those of 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.

Slope: The shear stress in soil or other unconsolidated material generally increases as the slope angle increases. Therefore, slope is one of the most important parameter for stability consideration (Lee *et al.*, 2004). Landslides are more prevalent in the steep slope areas than in moderate and low slope areas (Sharma *et al.,* 2011). Slope map was generated using the IRS-P5 stereo-paired Cartosat-I data and Digital Elevation Model (DEM) in a GIS environment. The hillside slopes are generally steep to very steep, and escarpments are common. 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, 45-60 and above 60 degrees. Weightage values are assigned in accordance with the steepness of the slope. The slope statistics of the area is given in Table 2 and slope map is shown in Fig. 3.

Table 1: Land use/land covers statistics of Mamit

Land use Class	Area (Sq. Km.)	Percentage
Heavy Vegetation	5.83	42.71
Light Vegetation	5.92	43.33
Scrubland	1.51	11.05
Built up	0.32	2.33
Barren	0.08	0.58
Total	**13.66**	**100**

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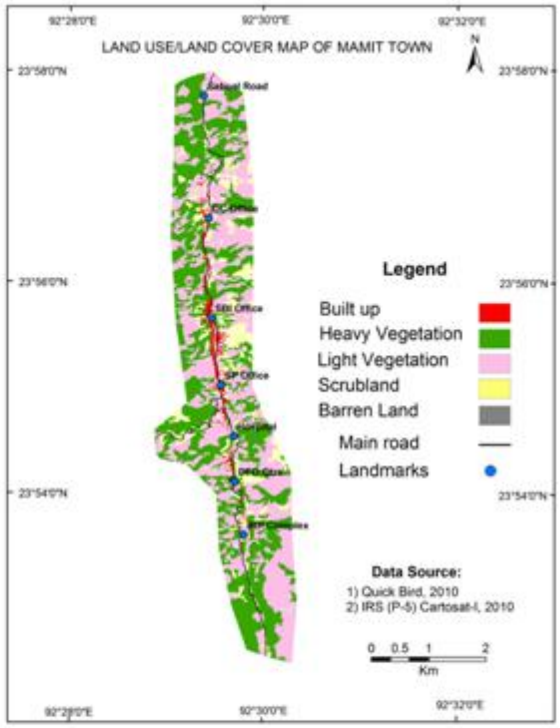

Figure 2: Land use / Land cover map of Mamit town

Table No. 2: Slope statistics of Mamit town

Degree of Slope	Area (Sq. Km.)	Percentage
0-15	2.97	21.72
15-25	4.82	35.26
25-30	2.21	16.19
30-35	1.65	12.08
35-40	1.00	7.32
40-45	0.53	3.85
45-60	0.46	3.37
>60	0.03	0.20
Total	**13.66**	**100.00**

Relative relief: The study area possesses high relative or local relief. The higher values indicate rapid rise in altitude and presence of faults, lower relief signifies mature topography. Relative relief is an important factor in landslide hazard zonation. It plays a decisive role in the vulnerability of settlements, transport network and land (Chandel *et al.*, 2011).

The highest point within the town area has an elevation of 855m from the mean sea level. The whole area was divided into High, Moderate and Low classes in term of relative relief with an elevation ranging from more than 800m, 600-800m and less than 600m 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.

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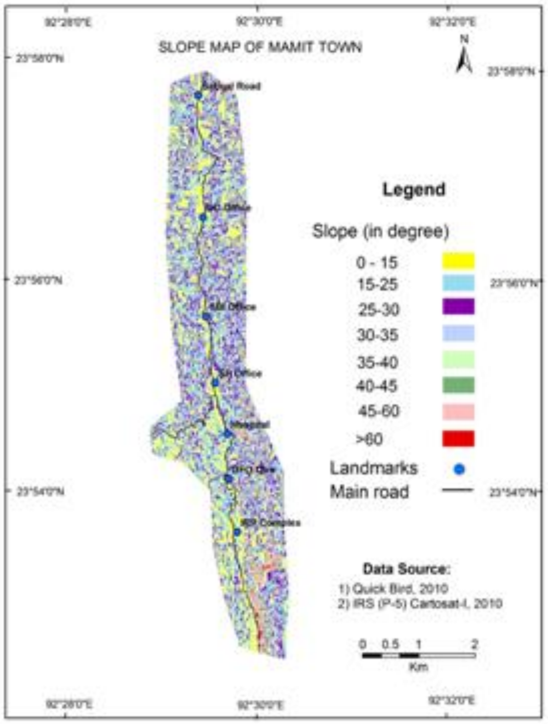

Figure 3: Slope map of Mamit town

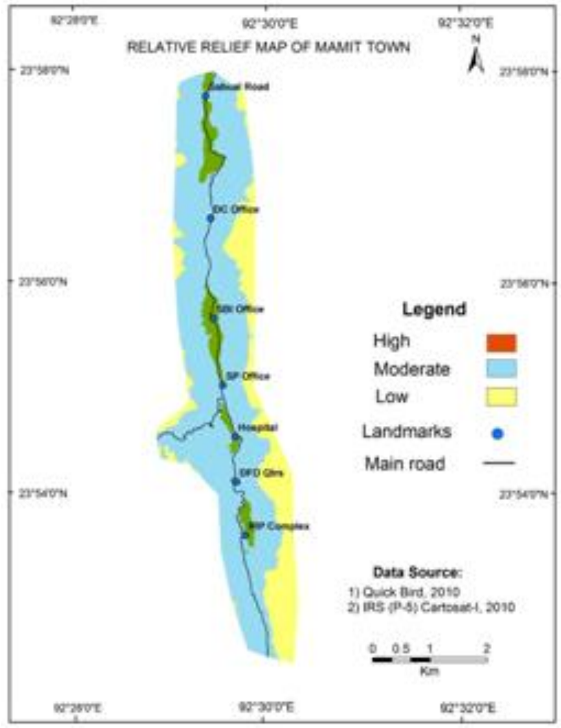

Figure 4: Relative relief map of Mamit

Table 3: Relative relief statistics of Mamit town

Relative Relief Classes	**Area (Sq.Km.)**	**Percentage**
High	0.89	6.48
Medium	9.77	71.52
Low	3.01	22.00
Total	**13.66**	**100**

Lithology: Lithology is one of the most significant parameters for landslide hazard zonation (Sharma *et al.*, 2011). The study area lies over Bhuban Subgroup of Surma Group of Tertiary age. Five litho-units have been established for the study area purely based on the exposed rock types of the area. These are named as Sandstone unit, Siltstone-shale unit, Shale-siltstone unit and Crumpled shale unit. The crumpled shale unit offers more chance of slope failure than any other units and hence highest weightage value is given. Lithological units comprising shale and siltstone are more susceptible to landslide than the hard and compact sandstone unit. 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 features like faults, fractures, joints, etc. can be observed and measured using remote sensing data (Kanungo *et al*,. 1995). Structurally, Mamit town forms two limbs of an anticline with approximately N-S trend which is almost symmetric in nature. It was observed that the rocks exposed within the study area are traversed by several faults and fractures of varying magnitude and length. Areas located within the vicinity of faults zones and other geological structures are 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.

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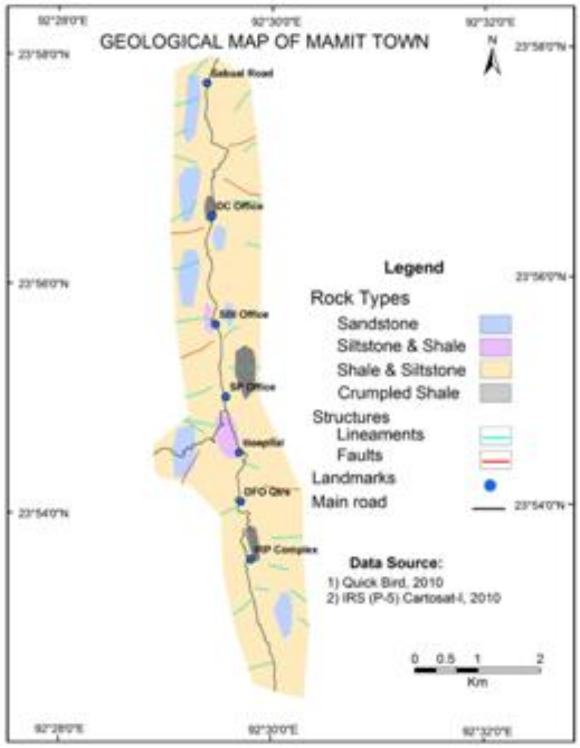

Figure 5: Geological Map of Mamit town

Table 4: Lithological statistics of Mamit town

Rock Types	Area (Sq. Km.)	Percentage
Sandstone	1.22	8.92
Shale-Siltstone	7.27	30.41
Siltstone-Shale	11.82	86.47
Crumpled Shale	0.36	2.63
Total	**13.66**	**100**

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 class in each parameter are carefully analysed so as to establish their relation to landslide susceptibility within the study area. Accordingly, weightage value is assigned for each class based on their susceptibility to landslides in such a manner that less weightage represents the least influence towards landslide occurrence, and more weightage, the highest. The assignments of weightage values 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 Joyce and Evans (Joyce and Evans, 1976) are combined and used in the present study as depicted in Table 5.

Table 5: Ratings for Parameters on a scale of 1-10

Parameter	Category	Weight
Lithology	Sandstone	4
	Siltstone & Shale	8
	Shale & Siltstone	9
	Crumpled Shale	10
Land Use / Land Cover	Heavy Vegetation	3
	Light Vegetation	5
	Scrubland	6
	Barren	7
	Built-up	8
Slope Morphometry (in degrees)	0 - 15	1
	15-25	3
	25-30	4
	30-35	5
	35-40	6
	40-45	7
	45-60	8
	> 60	5
Structure (Faults and Lineaments)	Length of Buffer distance on either side	8
Relative relief	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

Geologically, this zone is highly unstable and is at a constant threat from landslides, especially during and after an intense spell of rain. This is so, because, the area forms steep slopes with loose and unconsolidated materials, and includes 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. This zone is manifested on the surface by subsidence of the land as noticed in 'Bazar Veng' area. It further includes areas where road cutting and other human activities are actively undertaken. The Very High Hazard Zone is mainly found near High school-II, near Mamit College and within PWD complex. This zone constitutes an area of about 0.06 sq. km and forms 0.43% 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 and preferably left out for regeneration of natural vegetation for attainment of natural stability in due course of time.

High Hazard Zone

It mainly includes areas where the probability of sliding debris is at a high risk due to weathered rock and soil debris. It covers the area of steep slopes which when disturbed are prone to landslides. Most of the pre-existing landslide occurrences 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. Significant instability may occur during and after an intense spell of rain within this zone. Several lineaments, fractured zones and fault planes also traverse the high hazard zone. Areas which experience constant erosion by streams because of the soft nature of the lithology and loose overlying burden fall under this class. Vegetation is generally either absent or sparse. The High Hazard Zone is well distributed, particularly within the settlement area. It is mainly found to surround the Very High Hazard Zone as seen in Bazar veng locality. It is also found in the western side of DC Office, in the eastern side of Mamit Hospital. The High Hazard Zone is found more prominently in the middle and southern part of the study area. This zone occupies 0.49 sq. km which is 3.62% of the total area.

Plate 1: Landslide area in Mamit town where houses were dismantled

Plate 2: Areas with high slope angle coupled with unconsolidated sediments are susceptible to landslide as observed in Mamit town

The High Hazard Zone is also geologically unstable area, and slope failure of any kind may be triggered particularly after heavy rain. As such, allocation and execution of major housing structures and other projects within the vicinity of this zone should be discouraged. If unavoidable circumstances compel the execution of any such activity, due precaution should be taken in consultation with the geological experts. It is recommended that a thorough geotechnical investigation of the subsurface geology and hydrogeological condition of the area be made. In addition, afforestation scheme should be implemented in this zone, particularly of those species that help in stabilizing hill slope. 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. Setting up of settlement, as far as possible, is to be avoided within this zone.

Moderate Hazard Zone

This zone is generally considered stable, as long as its present status is maintained. It comprises areas that have moderately dense vegetation, moderate slope angle and relatively compact and hard rocks. Although this zone may include areas that have steep slopes (more than 45 degree), 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. Although this zone is generally considered stable, it may contain some pockets of unstable zones in some areas. 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 modification 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 relatively large area - about 0.14 sq. km. which is 51.83 % of the total study area.

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. Flatlands and areas having gentle slope degrees fall under this zone. This zone is mainly confined to areas where anthropogenic activities are less or absent, and is found predominantly in the western part of the town. 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 5.79 sq. km. and occupies 42.34% of the total study area.

Very Low Hazard 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.

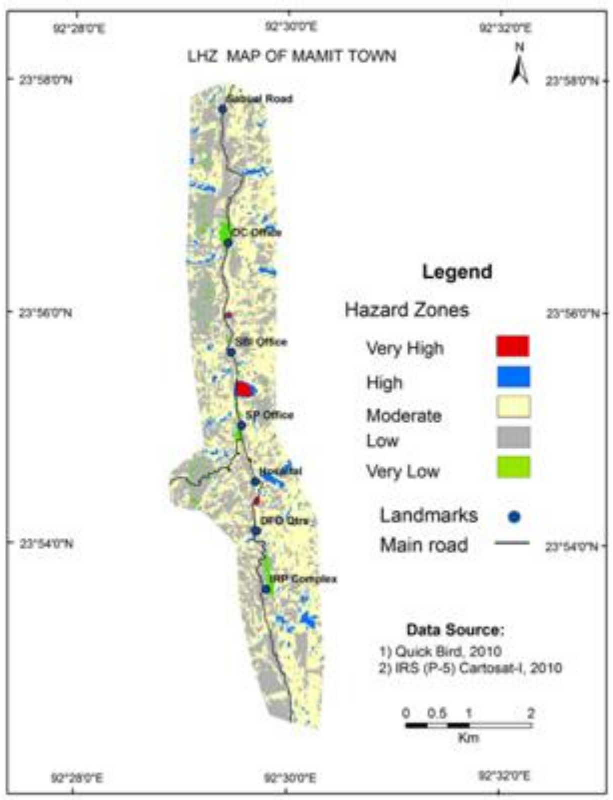

Figure 6: Landslide Hazard Zonation map of Mamit town

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 0.24 sq. km. and forms 1.78 % 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: Landslide Hazard Zonation statistics of Mamit

LHZ Code	Hazard Class	Area (Sq.km)	Percentage
1	Very High	0.06	0.43
2	High	0. 94	3.62
3	Moderate	7.08	51.83
4	Low	5.79	42.31
5	Very Low	0.24	1.78
TOTAL		**13.66**	**100.00**

Conclusion

It is observed that geo-physical factors like lithology, slope, geological structure and relative relief play an important role in landslide occurrence. Unlike other towns in Mizoram, the anthropogenic activity within the town area is still not creating major geo-environmental hazards. However, without proper planning for settlement expansion, construction of roads and other developmental activities, many parts of Mamit Township can become prone to landslide.

The present study has proven that Cartosat stereo data and Quickbird data together can be utilized for detailed landslide hazard zonation mapping in the hilly areas. It is observed that proper developmental planning with conservation measures of the physical environment within the town is necessary to prevent the occurrence of disastrous landslide in future. The outcome map can be used as a reference to suggest potential sites for the future growth of built-up areas. Therefore, the Landslide Hazard Zonation map prepared through this study will be useful for planning future developmental activities, and also for undertaking mitigation measures.

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