

Identification and Distribution of Landslide Hazard Zones in Aizawl City

Dr. Bobby Beingachhi

Dr. David Zothansanga

Abstract: Generalized hazard zone map of Aizawl city depicts the distribution of different prone areas of landslides in the city. Very low hazard zone covers the second smallest areas and distributed over the outskirts of the city. Low hazard zones are scatter but large areas are lying periphery of the city. Human activities and developmental works should be undertaken within these zones in consultation with experts. Moderate hazard zones extend over the largest areas of the city. The present condition of these zones may change to high hazard zones due to anthropogenic action. High hazard zones are also disperse in various parts of the city and several places of human settlement come under this zone. The Very high hazard zones cover the smallest areas and these zones are found at many places within the settlement areas. It is a constant treats of landslides especially during rainy season.

The extent of landslides prone areas depends on the steepness of the slope, the bedding plane of the rocks, the amount of vegetation cover and the extent of folding and faulting of the rocks. It is the rocks that break and carry with the soil debris. Removal of the vegetation cover, developmental activities, poor ground conditions, geomorphic phenomena, and long spell of heavy rainfall are the main responsibility of soil erosion, destabilization of slope and landslides.

Keywords: Lithology, Exogenetic, Fault, Toe Erosion.

Introduction:

Landslide is considered as one of the major natural environmental hazards in almost all parts of the world more especially in the mountainous regions. Due to the sudden and unpredictable occurrence of this disaster causes loss of a large number of precious life and property every year in different parts of the world. About 80% of all the landslides in different parts of the world are the result of anthropogenic factor. This phenomenon is a major environmental issue as a result of which it is essential to study the causes, impact, precaution and the mitigation measures for further occurrence.

Landslide is a major problem faced every year in Mizoram. The main causes of landslide are geological immature topography, high degree of slope, long spell of rainfall during monsoon season and human activities. The extent of landslides depends on the steepness of the slope. The steep bedding plane of stratified sedimentary rocks, the amount of vegetation cover, the weight of overlying materials, the water content of the soil and the removal of lateral support are another causes of landslide.

Rapid pace of urbanization in Aizawl result in a number of developmental works being taken up along the hill slope which reduces the stability of areas. These unplanned and unscientific development activities cause massive and micro landslides at many places. The anthropogenic action without consideration of geomorphic condition of the area

brought various parts of the city highly prone to landslides. Therefore, a number of landslides in and around the city are caused by nature and induced by human activities.

Rating for landslide criterions:

Mizoram Remote Sensing Application Centre giving weightage values to various criterions according to their assumed importance which brought about landslides based on the theoretical knowledge of the connoisseurs. They prepared landslides ratings for parameters on a scale of 1 to 10 while making micro-landslide hazard zone maps of Aizawl city. According to them, there are five major parameters viz lithology; slope morphometry (in degrees); structure (faults and lineaments); geomorphology and; land cover with vegetation. All these five major parameters consist more than four sub-categories except structure.

The lithology has been divided into five groups. One of the categories of lithology is crumpled shale which is the highest rating of this group and its weightage is assumed as 10 and shale sandstone unit is 9 on this scale which is the second highest ranking in the criterion of lithology. The siltstone-sandstone and sandstone are sixth and fourth position respectively. Regarding the parameter of structure, it is presumed as eighth although the rating scale depends on the length of buffer distance on either side of faults and lineaments.

In connection with geomorphology the highest weight of landslides is only four which has been found in the high structural hill. The second highest rating of landslide in geomorphic condition is established at three which is commonly lies in the medium structural hill. The low structural hill of geomorphology has been estimated as only three based on the above mentioned scale of landslide parameters.

In regard to slope degrees chance of possibility of landslides are predominantly increasing as the slope degrees ever more up to forty degrees and its weight has reached to six on this scale. Rating for landslide parameter in between 40 – 60 slope degrees are calculated roughly as eight weight but evaluated only five weight above 60 slope degrees category. Moreover, there are other relevant criterions are old occurrences of landslides, condition of vegetation cover, the vicinity of road cutting or excavation of materials, dip-slope relation and the drainage texture are predisposed and vulnerable areas to landslides.

Landslide Hazard Zones in Aizawl City:

Mizoram Remote Sensing Application Centre take up a major study of preparing micro landslide hazard zone maps on 1: 5,000 scale using Remote Sensing data. A number of thematic maps were procreated using Remote Sensing Technology and Geographical Information System (GIS) and minor landslide vulnerable area maps of Aizawl City depicting various groups of landslide endangered areas has been produced. The following interpretation of landslide vulnerable areas of the city were based on this thematic map

Very High Hazard Zone:

Very high hazard areas of landslide are generally located at many places where road passing through the slope of the land, excavation of materials for building construction, human activities are actively undertaken for developmental work and places loss the strength to resist the landslip down. Landslide is commonly found in the city where highly unstable condition of soil, scanty vegetation covers, steep slope with unconsolidated materials and weathered rocks. Soil debris covering sharply slope are incessantly taken away by the action of exogenetic forces. The rocks exposes to the surface has distinctive features of bedding and joint planes which provides the possibility of downward movement of a mass of soil and rock materials along the slope.

Very high hazard spread out widely over the entire area of Aizawl city. Within $92^{\circ}44' 00''$ to $92^{\circ}46' 00''$ E and $23^{\circ}48' 00''$ to $23^{\circ}50' 00''$ N very high hazard zone has been identified along Chhimluang lui and around Selekawn, Remand Home (Durtlang north), western side of MC Hall Durtlang, western areas of Presbyterian Hospital. Inside the degrees of $92^{\circ}44' 00''$ to $92^{\circ}45' 00''$ E and $23^{\circ}46' 00''$ to $23^{\circ}48' 00''$ N very high hazard zones are marked near Agape Camping Center, Central Store PHE Department. Very high hazard zone has also been located at PWD Complex, northern facing steep slope between Vaivakawn and Ropiabawk saddle and this area is not only steep slope but loose sediments, unconsolidated rocks and terrific speed of the sources of Tuikhur lui. Between $92^{\circ}42' 00''$ to $92^{\circ}44' 00''$ E and $23^{\circ}44' 00''$ to $23^{\circ}46' 00''$ N very high hazard zones are found around Dinthar saddle, from Lalsangliana petrol pump via Lalboi filling station, Singson servicing station extending from north-west along Sairang road up to Rangvamual, north and south of Electric veng, Ramhlun sport complex, western side of Hauva petrol pump.

Very high hazard areas are spatially distributed within $92^{\circ}44' 00''$ to $92^{\circ}46' 00''$ E $23^{\circ}44' 00''$ to $23^{\circ}46' 00''$ N around Aizawl Building Center, LAD; Govt. Godown Zuangtui, eastward facing steep slope between north Durtlang and Hermon Children Home. It also scattered on TNT, DOEACC, PWD Godown, south facing slope of Bawngkawn to Thuampui especially on all sides of Hauva Petrol Pump, in and around Power and Electricity power station, wayside slope between Thuampui and Zuangtui, vicinity of Gov't Primary Shool Thuampui and Primary School-1 Zemabawk. Another very high hazard zones are found close to High Court, southern area between Maubawk and Lawipu localities. Major patches of very high hazard areas are located near Dintharkawn, Bethlehem north, below AR Play Ground including Saron veng, eastern facing steep slope of soft sediments in Venghlui locality, western side slope of Maternity Hospital ITI and Tlangnuam play ground, eastward facing steep slope extending from Kulikawn to Melthum.

Very high landslide hazard zones are commonly found at the steep slopes with soft nature of rocks and unconsolidated materials, stone quarries, toe-erosion like road cutting and excavation of material for building construction, depth and lateral erosion of stream current on the hill slope and anthropogenic interferences. Some very high hazard areas are situated near faults and tectonically weak zones which are manifested on the surface by subsidence of lands. As calculated and recorded by Mizoram Remote Sensing Application centre this zones may occupies about an area of 6,44 sqkm and forms 44.99% of the total study area.

High Hazard Zone:

High hazard zone are found at various places on all sides of very high hazard zone. High hazard zone includes areas where probability of sliding debris is at a high risk due to the weathered rocks and soil debris covering steep slope. Several lineaments, fracture zones and fault planes also traverse the high hazard zones. High hazard zones covered and are of 33.33 sqkm which is 24.29% of the city as computed by Mizoram Remote Sensing Application Center, Science and technology.

High hazard zones scattered inside the degrees of $92^{\circ}44' 00''$ to $92^{\circ}46' 00''$ E and $23^{\circ}48' 00''$ to $23^{\circ}50' 00''$ N. This zone spread out from Selekawn to Sihphir vengthar play ground, western side of Agriculture Cold Storage, along the stream of Darlui and Kawmliam lui, eastern side of Gov't Sihphir High School, close to Twin Market in Sihphir. High hazard zone also extend from Thangrahbi saddle to Remand Home and small pocket of this zone has been marked along the western side of Sairang road, high hazard zone has been spread out from Hindi Training

College following Huahlam lui, around the areas of Durtlang dawrkawn and way to Women Polytechnics. It also includes the surrounding areas of Sihphir lui, Sailum lui, Midum lui and Leitan lui.

Between the degrees of $92^{\circ}44'00''$ to $92^{\circ}46'00''$ E and $23^{\circ}46'00''$ to $23^{\circ}48'00''$ N, high hazard zones covers an area around Sele lui, DD Kendra and Gospel Thunder Team Camping Center. Various dimensions of high hazard zones extend from Bawngkawn along the Sairang road including Vaivakawn, sothern facing slope of Bawngkawn, around Social Welfare Department, Ramhlun Indore Stadium, eastern side of Laipuitlang reservoir, southern side of Chandmari saddle and the entire areas of the tributary sources of Theihai lui. High hazard zone covers almost half of the entire area of Lungding lui, Kudam lui, near Zemabawk play ground, close to Gov't High School Zemabawk, southern side of Central Water Commission, northern side of Ramri lui and around the area of Mizoram Science Center.

High hazard zones and vulnerable to landslide are found in the south western facing slope of Khatla, Nursery, Bungkawn localities and also north east facing slope of Bungkawn and Maubawk localities. A part from these, high hazard zones are located near Dinthar saddle, Bethlehem north, Venghlui, Republic veng, Kulikawn and Tlangnuam. These zones are also found along the streams of Mualpui lui, Sihpui lui, Saisih lui, Vailui and Tuikual lui. Another prominent high hazard zones are found near RIPAN, TB Hospital Zemabawk, Beraw tlang and along the stream of Beraw lui. Highly vulnerable areas to landslides are identified at the western side of Chite lui up to Kangthelh lui. The entire eastern facing steep slope between Ngaizel and Hualnghmun are high hazard zone. These zones has been identified between Beraw lui and Tuikhur lui, Melthum locality to MST Workshop and also found around Hlimen playground.

Moderate Hazard Zone:

The moderate hazard zone has been distributed over several parts of the city. The sedimentary rocks which lies in the moderate zone hazard zone are usually hard and compact but its stability may bring down due to chemical reaction and mechanical action and toe-erosion or excavation of materials coupled with long heavy rainfall during monsoon season. As mentioned by the Mizoram Remote Sensing Application Center moderate hazard zone may include areas that have steep slope more than forty five degrees and this zone are covers with moderate dense vegetation. The orientation of the rock beds or the absence of overlying loose debris and human activity may make these zones less hazardous.

Generally, moderate hazard zone are stable rocks structure, firm and secure but it may contains pouches of precarious areas in certain places. For which reason this zone is needed spot verification and authentic investigation due to rapid growth of urbanization to take up precaution measures. Various development works and human activities should be taken up within the sphere of moderate zone cautiously so as to avoid wreak havoc in the area.

Moderate hazard zone covers an area of about 56.66 sq km and occupies 43.93% of the total study area¹. It spread over the largest areas of landslide hazard zone in Aizawl city. Three landslide hazard zones like very high hazard zone, high hazard zone and moderate hazard zone occupies not less than 94.43 sqkm (73,21%) of the entire area which indicates that most of the places are insecure for human settlement in Aizawl city. As such, it is vitally important to take step any developmental works in consultation with subject expert like engineers, geologists and geomorphologists etc. The government or authority should strongly propose to pass by-laws not to disturb or destroy natural drainage, vegetation or plants and undermine the slope etc within moderate hazard zone.

Low Hazard Zone:

Low hazard zone is normally considered stable and it has been located on the peripheral areas of the city. A reliable work on '*Micro landslide hazard zonation map of Aizawl city*' prepared by Mizoram Remote Sensing Application Centre, showing different categories of landslide hazard zones, with the help of Quick bird Satellite data, and the Indian Remote Sensing Satellite (IRS-P5) stereo-paired Cartosat-1 data depicted that a few small pockets of stable areas in the central part of the study area.

The slopes are gentle in low hazard zone where the chance of possibility of slope failure and landslide down are narrow. Normally, low hazard zone is located at the lower level of the investigated area where the various controlling factors of landslide having forceful impact on the stability of the slope are fall off or declining.

Low hazard zone is found in the western area of the city, south eastern part and also north eastern side of the study areas. The dimensions of the low hazard zone extend over an area of 26.58 sq km and forms 26.61% of the total study area. Low hazard zones are suitable for human settlement and eager to take up developmental works due to less chance of landslide if it is not big changes take place in this zone. Anthropogenic activities should be done in consultation with experts in case it may include small areas of unstable condition at various places.

Most of the low hazard zones are distributed at the outskirts of the city normally along the vicinity of the river valleys, low hazard zone are found at places of higher level of altitude. So, the nature of this zone is stable, hard, compact and having power to remain unchanged until big surgery by human interference and toe-erosion occur at any places. These areas are covered with vegetation but some places are bare plant, human activities for development are slowly come up as it was lying peripheral areas of the city.

As it was sedimentary formation the nature of soils are same to other places of Aizawl city but its stability to landslide are high and more secure for human settlement because the degree of slope, where the degree of slope are not more than thirty degrees which is not vulnerable to landslides. Flat and low level lands, stable and compact landscapes, low degrees of sedimentary stratified layers fall under the categories of low hazard zone.

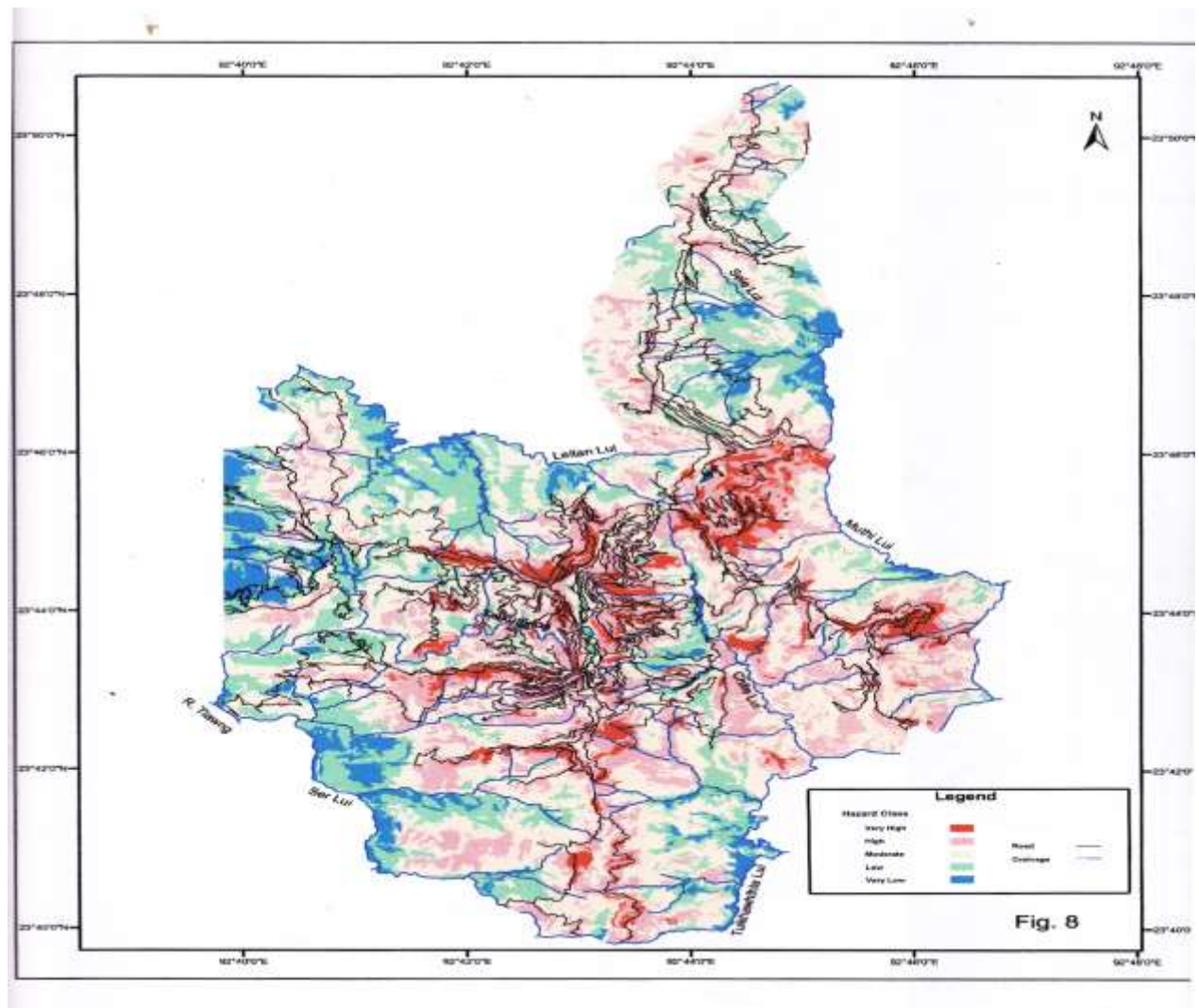
Very Low Hazard Zone:

Very Low Hazard Zone has been identified and distributed at various places mainly in the lower level of the study area. Very low hazard zone covers an area of about 7.97 sq km and forms 6.18% of the total area of the city (MRSAC-Micro Landslide Hazard Zonation Mapping of Aizawl City, pp 22). The areas of very low hazard zone has been found along the western side of Tuikhawhthla lui in south eastern corner of the city, along the western bank of Ramri lui, alongside the river valleys of Ramri lui and Sele lui and also present at and around the confluence of Chhuahlam lui and Zotuimawng lui in the north eastern part of the city.

Another very low hazard zones were located in the direction of the left bank Muthi lui and the surrounding area of the flowing together of Muthi lui, Pangen lui and Vainam lui. Small pocket of very low hazard zone has been marked in the central area of Aizawl city alongside Chite lui and also found on every side of LAD picnic spot. This zone is suitable for carrying out developmental works and secure for allocation of human settlement.

Very low hazard zone are spread out widely in the western and north western peripheral areas of Aizawl city. These zones are lying on the southern side of Sairang lui, Leitan lui including the entire area of Maumual. This low hazard zone has been found by the side of Kurung lui, some area of Tanhril local council come under this category and other very low hazard zone is situated on the eastern area of river Tlawng around the joining place of Tuikum lui and Tlawng lui. Low hazard zone is scattered to several places on every side of Aizawl Greater Water Supply Scheme phase-11 complex, between Serlui to Tuikum lui and Mizoram University campus to Blessing Home.

By and large, very low hazard zones are located at low level of land which includes valley fill and flat lands and is not much utilizing for human settlement despite very low hazard zone because its location are outskirts of the city. As recorded by the Mizoram Remote Sensing Application Centre the areas of very low hazard zones are nearly free from landslide for the present and future to come because it has been covers with dense vegetation and the dip direction of the rocks and slope angles are fairly low which kept the chance of slope failure is minimized in spite of soft nature of sediments and unconsolidated structure of rocks.



Landslide Hazard Zones Map of Aizawl City

Source: MIRSAC

Conclusion:

Mizoram being a hilly and soft nature of topography has come across a number of disasters especially with repetition of landslides at several parts of the areas. Every year, problem of landslides have been reported from various places during rainy season. Landslides in the state and also in the city brought about serious damage to private properties, terrible threat to public and loss of precious life. Due to landslide communication network remained closed for many days in many areas which caused severe privation to the people who get their foodstuffs and edible things from other places.

This has been a matter of the state as well as the study area is concern it is necessary to take appropriate mitigation measures. Landslide cannot be avoided totally in this area because it is hilly area of steep relief, receive seasonal heavy rainfall every year and geologically immature topography. Notwithstanding this landslides and its adverse effects can be mitigated by adopting certain remedial measures as under.

Hazard mapping: It locates areas prone to slope failure. This hazard mapping will give reliable information to the concerned department and NGO to plan execute and adopting preventive measures for landslide inside their respective areas. It can also help in identifying areas vulnerable to landslides and avoidance of areas for settlements, building construction and any other developmental works.

Engineered structures: Any construction works within and around the landslide prone area should be done in consultation with engineers, geologists, geomorphologists and experts. Buildings and other engineered structures with strong foundations are in a better position to withstand the ground movement forces. Underground installations such as pipes and cables should be made flexible to move in order to withstand forces caused by landslides.

Land use/terracing: Land use and terracing pertains to preservation of soil erosion caused by external forces and human activities. Denuded path slopes provoke landslides and must be protected through land use like tracing. Due care must be taken in order to avoid increasing pressure of human, animal needs, rapid denudation and biotic interference etc have further aggravated the problem of landslides.

Check dam: Terrific speed of running water on the slope and storm water causing lateral and vertical corrosion and erosion. The rock fragments, pebbles, debris and waste materials roll down along the bottom of the stream widen and deepening the cause of the streams year by year which hampered stability of the soil and its adjoining areas. The landslide took place due to the complete removal of materials which support upper part of the rock mass. In this situation, mitigation measure to be taken in construction of check dam across the streamlet.

No human activity: No human activity be undertaken in the landslide prone areas and past occurrences of landslide. The vulnerable area to landslide has to be entirely avoided for settlement and other construction works. It should be left out for re-generation of vegetation to attain stability during the course of time through the physical processes active in the areas. It should be checked human interference in the hazard zone of landslides as far as possible.

Proper drainage: Proper drainage should not be neglected. The side drain and culvert passages should be put under stick vigilance to escape accidental blockage during heavy rain, constructing roads and building etc. Gutter water and rain water from the roof of the house also should be kept away to the nearest drainage, properly and carefully.

Increasing vegetation cover: Whenever possible plant trees and increasing vegetation on the slope with grasses, shrubs and trees should be implemented in the landslide prone areas. This is the cheapest and the most effective away of mitigation of landslides. Plantation of those species helps in binding the top layer of the soil with layer below while preventing excessive run off and soil erosion.

Retaining walls: It is apparent that landslides may occur when either shearing forces increase or shearing resistance of material decreases. Construction of retaining wall along the road side is very helpful to increase resistance to check debris slide down. Removal of slide debris to reduce the weight of material is imperative need in order to avoid landslide at many places.

Developmental works: Due to rapid pace of urbanization in the city a number of developmental works are being taken up at various places without considering geomorphic condition. Removal of underlying support and toe-erosion weakened the resistance of material which affect the land stability. The human activities coupled with heavy rainfall caused landslides at several places during rainy season. The allocation of major structure should be permitted only in local safe areas.

Excavation of materials: The avoidance of excavation of the materials for building and road construction in and around the areas of steep slopes, old slides or recognizable landslides and hazard areas is important to escape to landslide. It is estimated that the construction of just one kilometre long road required removal of 40,000-80,000 cubic metres of debris, which slide down slopes, killing vegetation and choking mountain streams.

By law: As a consequence of fast growing of Aizawl city and increasing in population result in more human activities along the hill side enhanced the instability of the area at various places. The areas vulnerable to landslide should be identified to declare certain areas are totally prohibited, some areas are restricted and other places are free areas as its condition of stability. For that, it is necessary to have by law to resist the encroachment of the prohibited areas.

It is expected that these mitigation strategies will give valuable information to concerned persons, various organization and disaster management etc to apply and to execute at the vulnerable areas to landslide within their respective spectrum of operation.

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