Landslide Hazard Zonation along NH 54A from Lunglawn to Zotlang in Lunglei, Mizoram, India

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Abstract

The state of Mizoram in North East India is a landslide prone one. It is a landlocked state bordering Myanmar to its east, Bangladesh to its west and the State of Assam to its north. In recent years Lunglei witnessed two devastating landslides in 2018 and 2019 with numerous loss of life and property. The loss incurred from natural and man-made disasters in other areas in the State too has led to tremendous loss of money to the exchequer, particularly landslides. Many of the landslides are results of combinations of geology, geomorphology, topography and anthropogenic activities. The seasonal rains served as triggering causes of these landslides on many occasions especially during the monsoons.

Landslides in general have caused numerous casualties with immense economic losses and they will continue so in this hilly and mountainous region like Mizoram unless sound and effective scientific decisions and measures are not adopted by the people and the authorities. Identification of landslide hazards of urban areas situating on tops of mountainous ridges like Lunglei is essential for minimizing losses due to landslides and other mass movements. This study encompass an area of 8.86 sq kms transversing the Lunglei town from Lunglawn to Zotlang localities with the NH54A being buffered with 500m on both sides in homogenous domains and the obtained results classify the study areas ranking them accordingly to the potential landslide hazard threat they can cause in future.

Keywords: Landslides, hazards, zonation map, ArcGIS 10.3, geology, Lunglei.

Introduction

Lunglei town is the capital of Lunglei district and it serves as a link to the northern and southern corridors of Mizoram in North East India. It is the point of entry for all the commercial and essential commodities entering the southern, south eastern and south western ends of the state. The whole study area falls within Survey of India Toposheet no. 84B/09 and it lies within 22°55'26.43"N and 92°45'8.59"E and 22°55'26.43"N and 92°46'1.35"E. The highest elevation point has values of 1100 m in the study area and it covers a length of 9.28km along the NH54A.

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Lunglei is the largest town of Mizoram with inhabitants of 57,011 according to the 2011 census conducted by the Ministry of Home Affairs, Govt. of India and it is currently the hub of administration, educational, political and is also the centre of modern urbanization. Lunglawn and Zotlang are two localities amongst the 32 localities within Lunglei town and the location map of the study area is shown in fig. 1.

Geology and Structure

Lunglei is located in the south central part of Mizoram which is a part of the Surma basin. Geologically, it is a landscape with young and folded mountains with flysch and molasse deposits having immature topography. The Tripura-Mizoram basin is represented by successive repetitions of Paleogene and Neogene sediments[1]. The sedimentary succession of Mizoram has been geologically subdivided into the Barail (Oligocene), the Surma (Early to Middle Miocene) and the Tipam groups (late Miocene to early Pliocene) in ascending order[8].

The Surma basin is bound by post Barail unconformity[4]. The Surma basin exposes the alternate arenaceous and argillaceous sequences reflecting epeirogenetic movements throughout the time of deposition[6]. Lunglei rocks are of Surma Group of rocks and are assigned Middle Bhuban formation in age.

A series of NW-SE trending anticlines and synclines is common with sharp erosional and weathered rocks which can be seen in many lithological units. The area is undergoing rapid transformation with anthropogenic activities contributing to the many causes of landslides. Sandstones, shale-sandstones, shale-siltstones and crumpled shales are the dominating rocks in the study area and these rocks are subjected to jointing, fissured, sheared in few places.

The rocks display cross bedding, lenticular bedding with body fossils found in small pockets amongst the few horizons. Discontinuity in bedding in some areas with thick soil covers also adds to the landslide hazards in some areas. The soils are of fine loamy soils and excavation of such soil covers and rocks in the form of toe cutting and slope cutting; unproper drainage channels also have had triggered small landslides in these areas.

The study covered all geological fieldworks covering the whole study area to generate Stereonet diagrams of both Lunglawn and Zotlang which are shown in fig. 2 and fig. 3 and lithologs of Lunglawn and Zotlang in fig. 4 and fig. 5. Dip amounts, dip directions and planes for Lunglawn and Zotlang are given in table 1 and table 2.

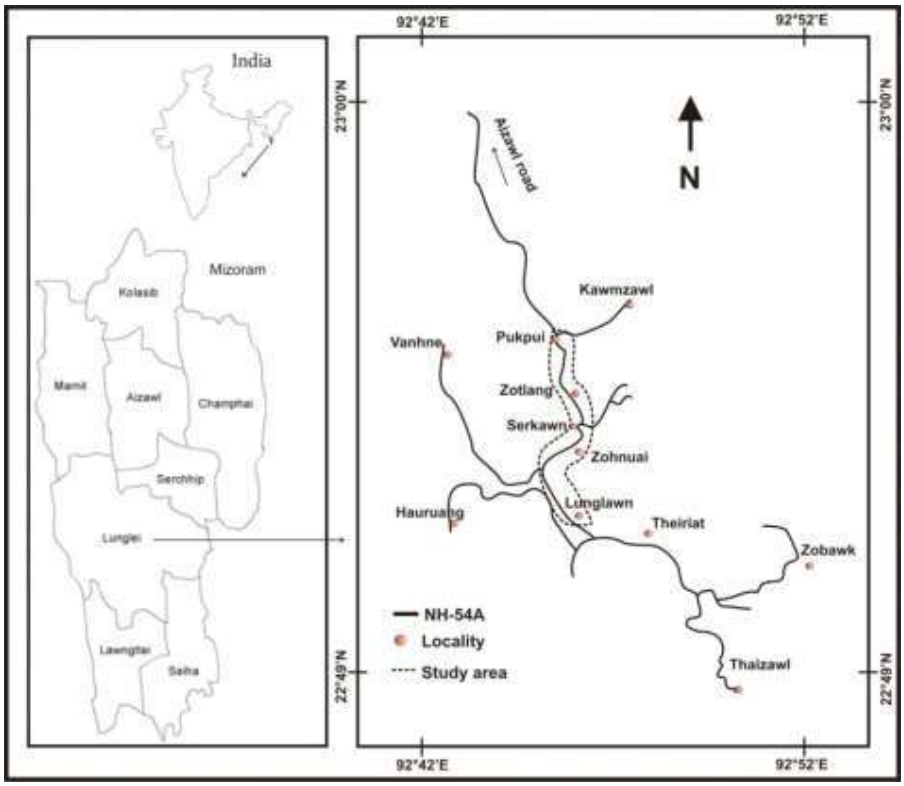

Fig. 1: Location map of the study area

Table 1
Dip Direction and Dip amount of rocks of Lunglawn

S.N.	Dip Direction	Dip Amount	Plane
1	163	19	Bed
2	172	15	Bed
3	189	18	Bed
4	152	16	Bed
5	149	7	Bed
6	348	8	Bed
7	163	23	Bed
8	312	10	Bed
9	6	26	Bed
10	43	4	Bed
11	141	24	Bed
12	17	16	Bed
13	182	10	Bed
14	22	38	Bed
15	4	8	Bed
16	13	35	Bed
17	37	22	Bed
18	38	29	Joints
19	21	27	Bed
20	346	48	Bed

Table 2
Dip Direction and Dip amount of rocks of Zotlang

S.N.	Dip Direction	Dip	Planes
1	40	80	Bed
2	12	47	Bed
3	114	49	Bed
4	148	85	Bed
5	349	23	Bed
6	109	41	Bed
7	106	33	Bed
8	72	45	Joints
9	75	50	Bed
10	58	30	Bed
11	114	35	Bed
12	133	27	Bed
13	164	39	Bed
14	27	38	Bed
15	42	33	Bed
16	37	31	Bed
17	28	33	Bed
18	43	44	Bed
19	51	53	Bed
20	65	85	Bed
21	67	85	Bed
22	81	82	Bed
23	84	36	Bed
24	66	78	Bed
25	57	82	Bed
26	41	76	Bed
27	83	57	Bed
28	74	29	Bed
29	96	56	Bed
30	48	73	Bed

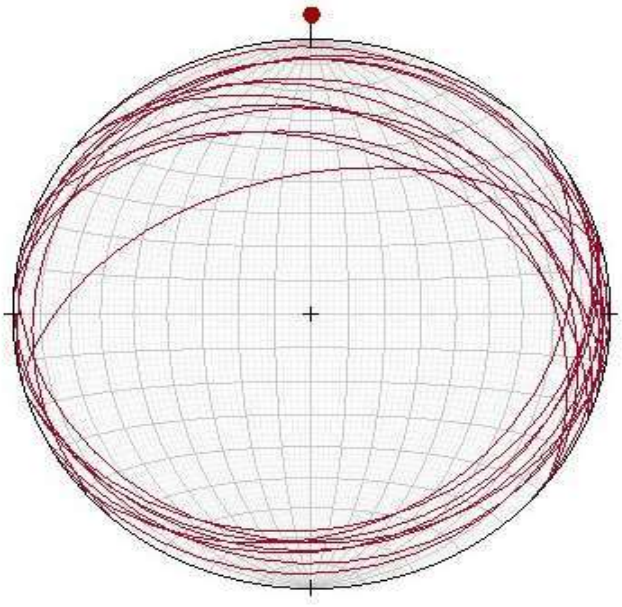

Fig. 2: Stereonet diagram of Lunglawn

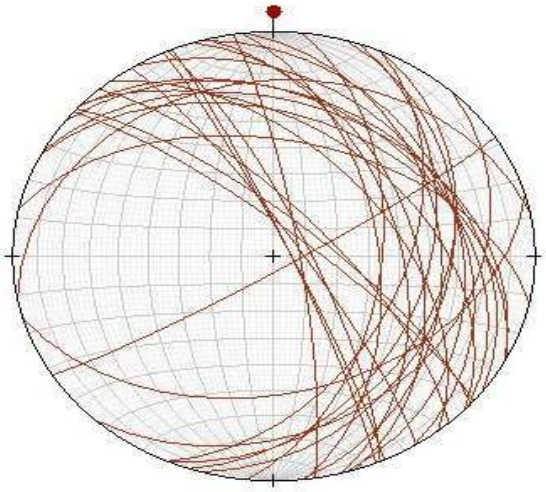

Fig. 3: Stereonet diagram of Zotlang

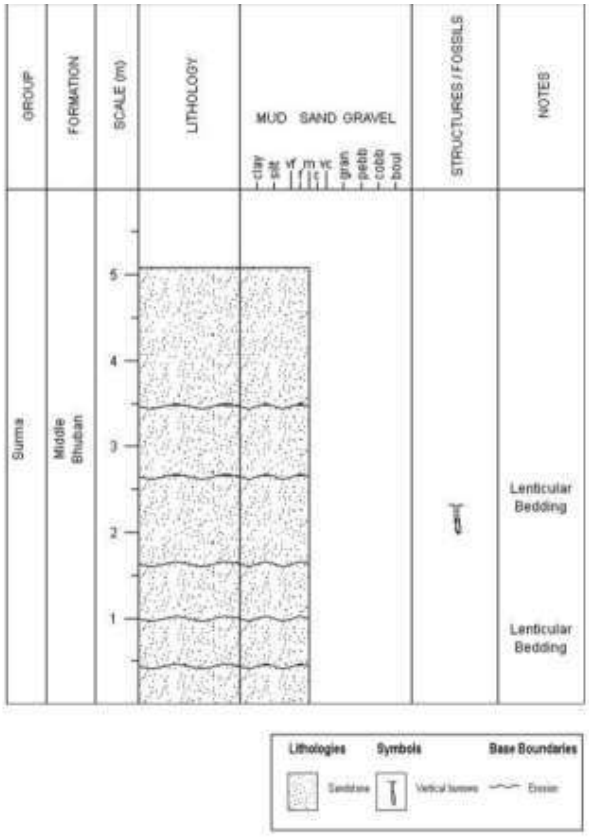

Fig. 4: Litholog of Lunglawn

Recent landslides within the study area

In recent years, two notable devastating landslides occurred within the study area. The Lunglawn landslide incident which took place on 04.06.2018 damaged one house in which a family of 10 people lost their lives and the College Veng Landslide which occurred on 12.07.2019 was a major disaster in which 7 buildings were damaged, displacing 12 families. In the Lunglawn landslide, the house was constructed on the crown of the slide where slope cutting was done extensively below the slide posing a threat to their house. Weathered shales formed the bedrock and continuous rainfall for days and nights triggered this Lunglawn landslide. The College Veng landslide was a case of translational landslide which was caused mainly by unproper developmental activities, continuous heavy rainfall and unproper drainages.

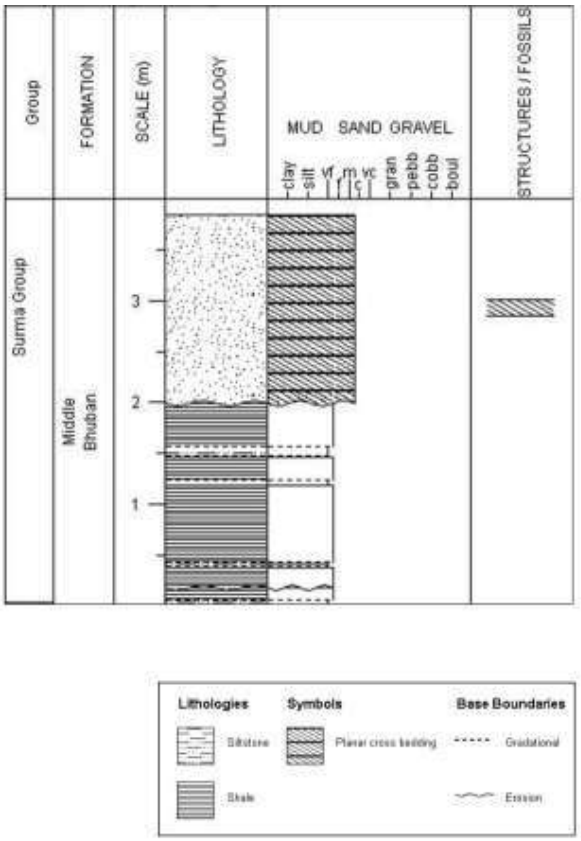

Fig. 5: Litholog of Zotlang

Review of Literature

The first modern attempt to prepare a landslide hazard zonation map led to numerous attempts to study and classify landslide hazards[11]. The first landslide hazard zonation map in Mizoram was prepared for a roadside section between Rotlang East and Hrangchalkawn in Lunglei District. These areas are located in the south eastern and southern areas from modern Lunglei town and the length of the roadside section studied was roughly about 40 kms in total[9]. GIS was then incorporated for the study of landslides in Mizoram which were later used to prepare disaster management plans[3]. Geotechnical techniques were then incorporated for the study of landslides of Mizoram.

The first one of such was introduced in the study of Ramhlun Vengthar landslide where poor drainage system, toe cutting and steepness of slopes all added to the causes for the landslides[2]. The first micro zonation of landslide hazard zonation in Mizoram was then prepared between Aizawl city and Lengpui Domestic Airport[5]. To assess the stability of rock slopes on road cut sections from Kulikawn Aizawl, rockmass characterization and numerical simulation were carried out which confirmed the various failure observations[7] and Limit Equilibrium Method study was carried out in Rangvamual in Aizawl where it was concluded that the dip slip failure was one of the causes for the Rangvamual landslide[10].

Material and Methods

Toposheet No 84B/09 having a scale of 1:50,000 prepared by the Survey of India was used for the study area. Under a GIS environment, the toposheet was scanned in JPG format and was georeferenced using Ground Control Points (GCP) which were later digitized in an *ArcGIS* 10.3 software. *QuickBird* and *WorldView* satellite imagery of 0.8m were also used.

For precise and accurate reading of locations, co-ordinates were obtained by using Garmin GPSMAP 78S. The rainfall data were obtained from Department of Economics and Statistics, Department of Agriculture, Department of Agriculture, all of which are under the Govt. of Mizoram. MIRSAC, ICAR and Statistical Handbooks of Mizoram too provide valuable insights.

Selection of seven causative factors viz. lithology, soil, slope morphometry, relative relief, land use/land cover, rainfall and lineament was the area of interest for the study. Each causative factor was converted to a thematic map and the parameters were analysed to establish their relation to landslide susceptibility. Accordingly, rank values were assigned to each parameter, starting from 1 to 100 where the sum of the ranks of all parameters equals 100. The flow chart for methodology is given in fig. 6.

Results and Discussion

Slope: The slopes of the area are represented in terms of degrees and are divided into five slope facets viz. <15, 16-25, 26-35, 36-45 and >45 degrees. Weightage values are assigned in accordance with the steepness of the slope where steeper slope has higher weightage value than the gentler slope. The slope statistics is given in table 3 and the slope map is given in fig. 7.

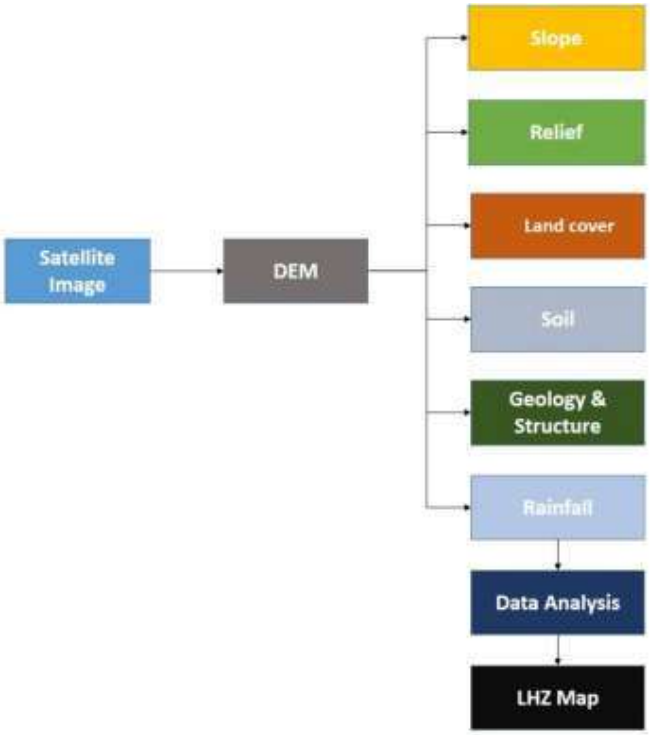

Fig. 6: Flowchart for Methodology

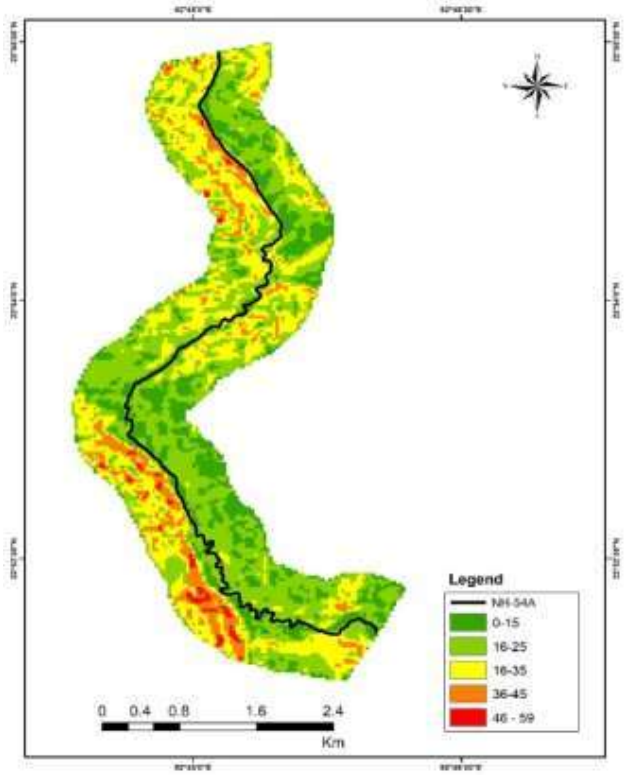

Fig. 7: Slope Map

Relative relief: Relief of the study area is divided into High Relief, Medium Relief and Low Relief. This map represents variations of altitude of the study area in Lunglei with respect to their difference in height between the highest and lowest points. The statistics are given in table 4 and the relative relief map is given in fig. 8.

Lithology: The study area is composed of limited rock types viz. sandstones, shale-sandstones, shale-siltstones and crumpled shales. For the occurrence of landslides, the crumpled shales are the most susceptible rock type and their weightage values are assigned for each of the rock types. The percentage for the lithology is given in table 5 and the lithology map is given in fig. 9.

Table 3
Slope data

SlopeAngle	Category	Area (Sq.Km.)	Percentage
$<15^0$	Very gentle slope	1.64	18.42
16^0 -25^0	Gentle slope	3.87	43.57
26^0 -35^0	Moderately steep slope	2.55	28.73
36^0 -45^0	Steep slope	0.74	8.32
$>45^0$	Escarpment/cliff slope	0.08	0.96

Table 4
Relative Relief data

Relative Relief	Category	Area(Sq. Km)	Percentage
<100m	Low relief	-	-
101–300m	Medium relief	-	-
>300 m	High Relief	8.86	100

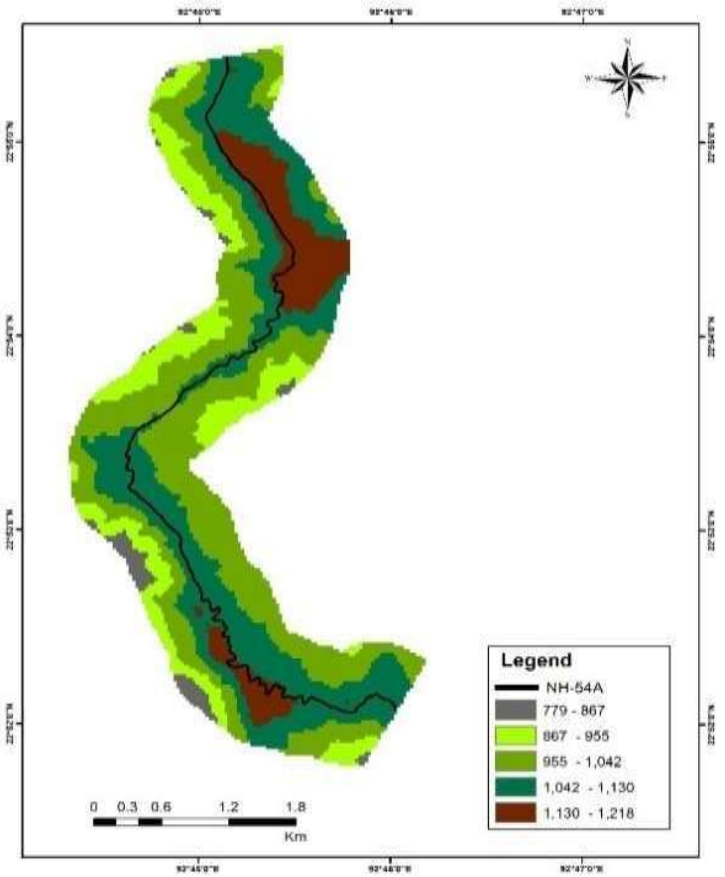

Fig. 8: Relative Relief Map

Table 5
Lithology data

Rock Type	Area (in Sq. Km)	Percentage
Sandstone	0.85	9.59
Shale-Sandstone	1.55	17.53
Shale- Siltstone	6.42	72.48
Crumpled Shale	0.04	0.40

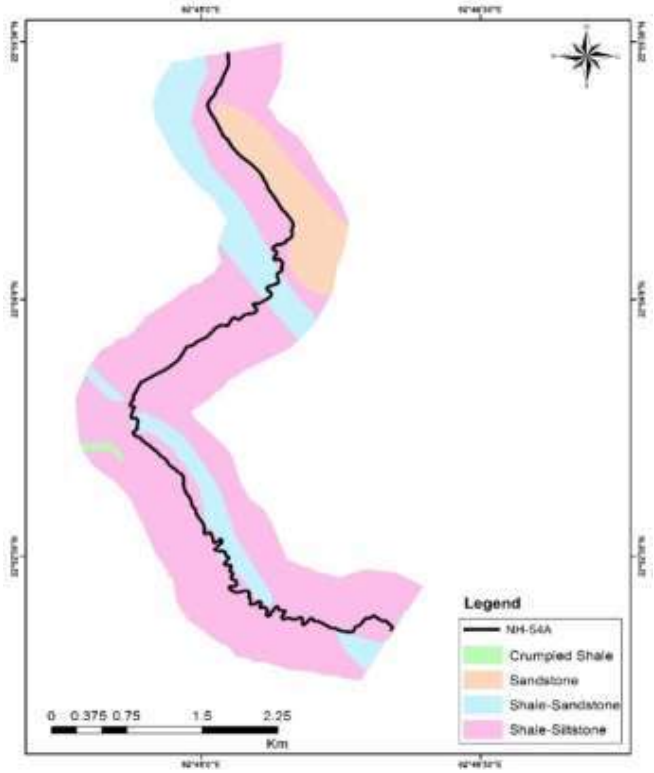

Fig. 9: Lithology Map

Table 6
Land Use/Land over

Land Use Class	Area (in Sq. Km)	Percentage
Built-up	3.75	42.39
Heavy Vegetation	1.10	12.39
Light Vegetation	0.45	5.13
Scrub/Tall grass	3.55	40.08

Table 7
Soil

Soil Type	Area (in Sq. Km)	Percentage
Fine loamy	8.86	100

Land use/land cover*:* The study area is divided into four land use/ land cover classes viz. Built Up Land, Heavy vegetation, Light vegetation and Scrubs/Tall grasses. The areas covered by heavy vegetation were found to be the least susceptible to landslide. Hence, the heavy vegetation class is assigned low weightage value. The built up land areas are more prone to landslides than the other classes and are given higher weightage values. The statistics and percentage of land use/land cover is shown in table 6 and the land use/land cover map is given in fig. 10.

Soil*:* The soils between Lunglawn and Zotlang are moderately deep where some soils are excessively drained on moderately dissected hill slopes having loamy surfaces with moderate erosion. The soil statistics is shown in table 7 and the soil map is given in fig. 11.

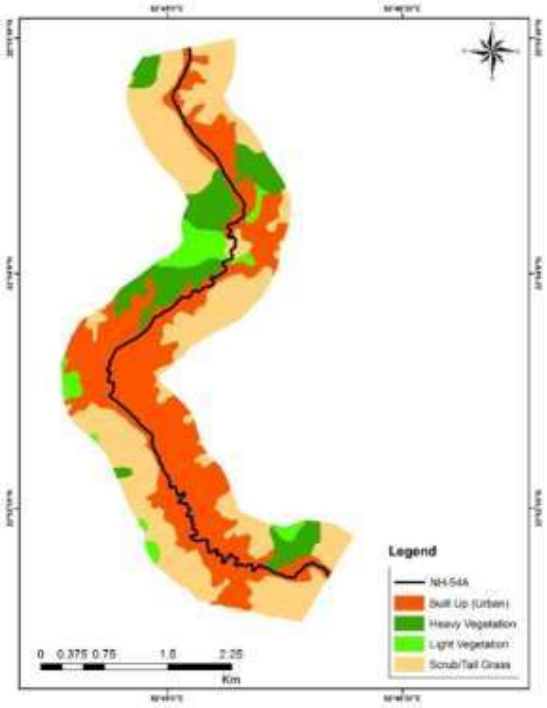

Fig. 10: Land Use / Land Cover Map

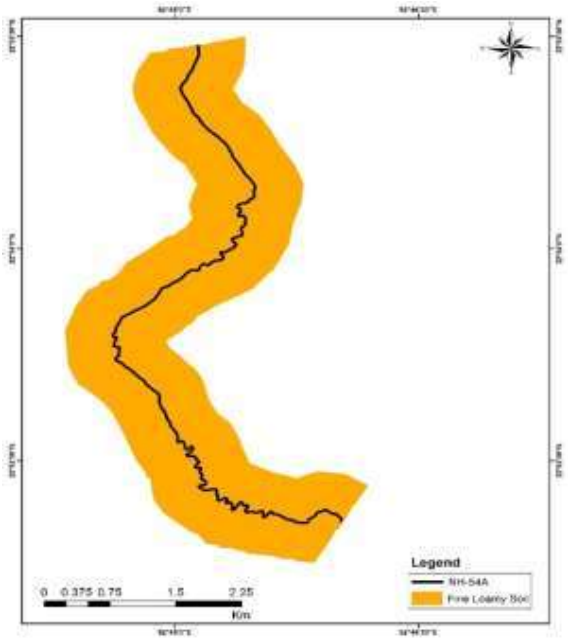

Fig. 11: Soil Map

Lineament feature*:* The planes of weakness which are present in the rocks are interpreted as lineaments. When these are subjected to intense weathering, erosion, rainfall, tectonic movement or due to anthropogenic activities, their presence could potentially trigger any mass movement which includes landslides. The lineament feature map is given in fig. 12.

Rainfall map*:* The annual meteorological data collected from Department of Economics and Statistics, Department of Agriculture, Department of Agriculture all helped in preparing the rainfall map. The rainfalls which are always high in the months of July and August can have triggering effect many landslides and mudslides.

The two notable landslides which occurred in 2018 and 2019, occurred during the high intensity rainfall months of July and August. The annual rainfall data for Lunglei between 1999 and 2020 data is given in table 8 and the rainfall map in fig. 13.

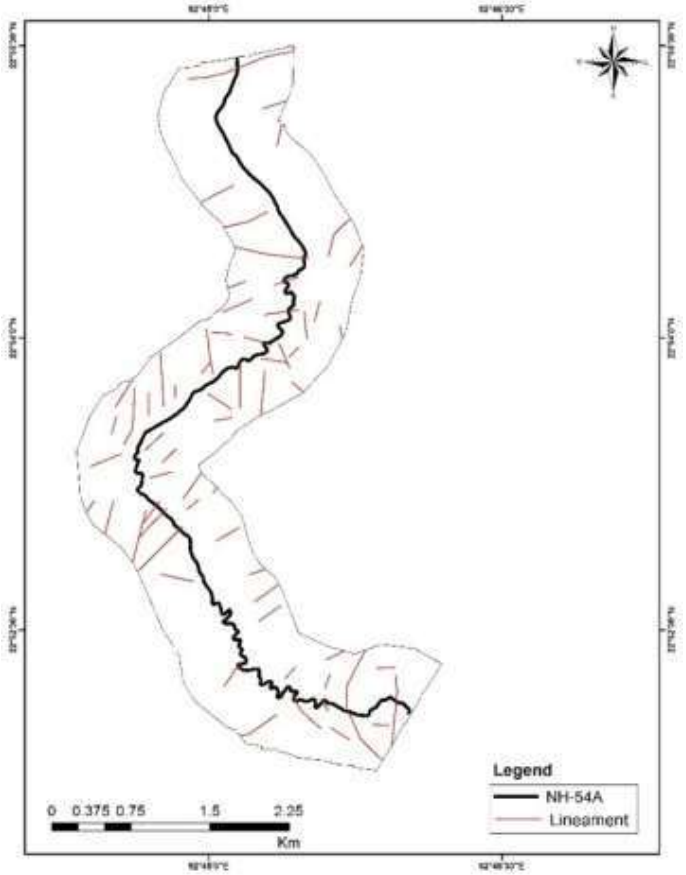

Fig. 12: Lineament feature map

Table 8
Annual rainfall data of Lunglei town from 1999 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1999	N/A	1	20	25	440	780	760	615	710	400	10	101	3862
2000	6	3	170	291	700	900	872	1423	400	250	99	N/A	5114
2001	N/A	8	10	49	623	775	622	521	430	371	220	N/A	3629
2002	24	2	73	71	741	530	984	543	312	85	141	N/A	3506
2003	N/A	1	22	53	224	1196	470	620	581	172	N/A	27	3366
2004	N/A	2	23	295	296	1210	919	535	591	173	15	N/A	4059
2005	N/A	1	80.1	124.8	267.6	271.9	516.2	622.2	436.3	412.6	N/A	12.8	2745.5
2006	N/A	N/A	N/A	30	486	710	345	203	214	236	N/A	N/A	2224
2007	N/A	55.2	1.8	173.6	454.5	701.9	804.2	910.7	945.4	317.1	73	N/A	4437.4
2008	7.2	8.1	29.3	N/A	N/A	440	200	431.5	150	210	N/A	N/A	1476.1
2009	N/A	N/A	150	321	N/A	389	430	830.2	482.4	198.2	169.1	N/A	2969.9
2010	1	85.8	256	350	350	650	730	669	675	350	110	10	4236.8
2011	2	59	87	55.4	607.9	574	495	749.3	489.5	192.9	98	N/A	3410
2012	N/A	5	17	338	278	903	870	1121	508	529	124	320	5013
2013	2	5	45	147.3	841	823.9	689.2	826.3	597.8	221.2	170	100	4468.7
2014	5	44.8	15	20.3	320	381	330	520.3	687	142.8	12	12	2490.2
2015	13.2	35	38.9	170.8	93.8	525.3	714.8	668.3	609.3	220	12	10	3111.4
2016	5	29	49	23	308.9	670.6	465.2	426	483.7	176.6	85	15	2737
2017	3	36	103	290.4	173.9	518	533	599.4	497.8	259.8	25.1	38.4	3077.8
2018	2	23	300	216	934	950	540	600	175	376	28	11	4155
2019	14.4	30	23.4	124.4	175.8	685.1	374.1	347.3	189.7	207.1	13	25.6	2209.9
2020	4	67.1	57.9	86.3	174.5	364.4	194.5	364.4	727.3	328.4	98.8	15.6	3022.1

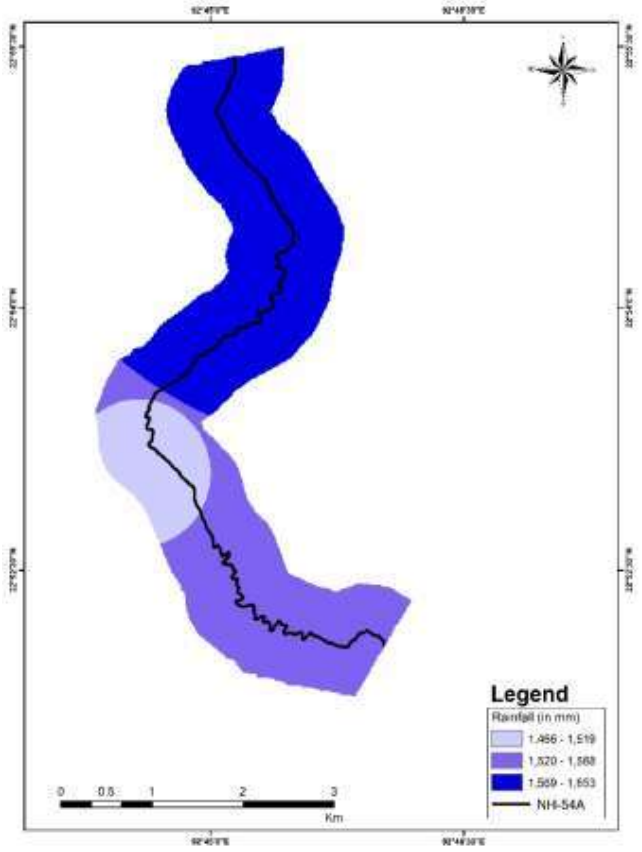

Fig. 13: Rainfall map

Table 9
Parameters and Readings

Parameter	Rank	Category	Rating
Slope Morphometry	20	Very gentle slope	2
		Gentle slope	4
		Moderately steep slope	6
		Steep slope	8
		Escarpment/cliff slope	5
Relative Relief	10	High Relief	4
Land use land cover	15	Built-up	8
		Heavy Vegetation	3
		Light Vegetation	5
		Scrub/Tall grass	6
Lithology	25	Sandstones	4
		Shale-Sandstones	6
		Shale- Siltstones	8
		Crumpled Shales	9
Geological Structure		Length of buffer distance on either side	8
Soil	10	Fine Loamy	5
Average Annual Rainfall	20	Moderate	7

Lunglei landslide hazard zonation map between lunglawn and zotlang*:* The landslide hazard zonation map represents the areas where potential landslides can occur in the future in which the high hazard areas correspond to areas of high frequency of landslides between Lunglawn and Zotlang of Lunglei town. The landslide hazard zonation map of Lunglei town between Lunglawn to Zotlang along the NH54A is given in fig. 14 and the different parameters and their rankings are given in table 9.

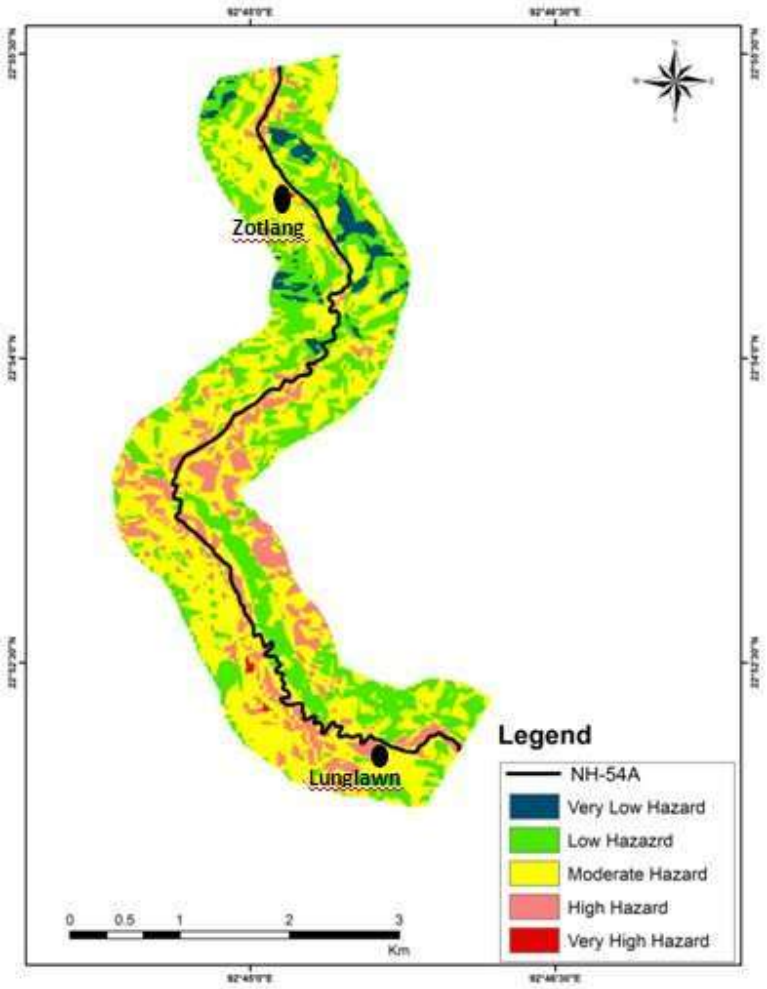

Fig. 14: Landslide hazard zonation map of Lunglei town between Lunglawn and Zotlang

Conclusion and Recommendation

Combining all the parameters and by giving weightage values, the final LHZ along NH 54A from Lunglawn to Zotlang in Lunglei is prepared on a scale of 1:25,000. Of all the total 8.86 sq km of the study area, the moderate hazard zone (MHZ) occupies the largest area with 4.56 sq km which is 52.17 % of the total study area. The low hazard zone (LHZ) which occupies 2.69 sq km encompass 30.76 % of the study area followed by the high hazard zone (HHZ) which is roughly about 1.21 sq km in area, this makes up about 13.95 % of the total study area. The very low hazard zone (VLHZ) makes up 0.26 sq km of the total area and the very high hazard zone (VHHZ) is about 0.01 sq km of the study area which is 0.17% of the total study area.

As the study site lies along the national highway 54A which is the life line of Mizoram. Highway connects both the northern and southern ends of Mizoram. Occurrences of disasters in the form of landslides due to geological, geomorphological, physical or anthropogenic causes could potentially block the roads for days delaying any traffic movement. It is therefore highly recommended that tree plantations should be encouraged, announcement of No Development Zones in areas falling in the high hazard and very high hazard zones, development of proper drainages, frequent use of meshing like gabions, construction of retaining walls, terracing along the roads, development of site development and slope modifications for Lunglei town by the authorities etc. would mitigate landslides from occurring and reduce the risk of damages and casualties in the future.

Acknowledgement

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