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Zonation Mapping Techniques of the Landslide Hazard in the Facet Area along NH 10 (Sevok to Tista Bazar) and Kalimpong-Lava-Garubathan Roads, Kalimpong District, Darjeeling Himalaya

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Abstract: Kalimpong District in the Eastern Himalaya in West Bengal, India has been intensely destabilized by many landslides. Recently the incidence of landslide occurrence has increased rapidly with the gradual anthropogenic abuse of slopes specially the development of transport arteries and consequent jerk and vibration by vehicles. Due to landslides, the Darjeeling Himalayan region faces major problems of geoenvironmental imbalance and poses threats to life and property Therefore; landslide hazard zonation mapping becomes indispensable to identify the risk zone for future prevention and management of such hazards. With this view in mind, the present paper takes an attempt to undertake the work of landslide hazard zonation mapping of Kalimpong district, Darjeeling district.

Keywords: Landslide hazard; Zonation mapping; Landslide hazard evaluation factor; Slope facet map; Total estimated hazard.

INTRODUCTION

The Darjeeling Himalaya is a fragile terrestrial system, which is too often disturbed by various environmental catastrophes. Slope instability along transport and arterial sectors is perhaps the most hazardous among the environmental catastrophe threatening the Darjeeling Himalaya. Nowadays landslides especially along the transport and arterial sectors of Darjeeling Himalaya are creating serious problems leading to total disruption of vehicular traffic between the hills and the plains with the consequent disastrous effect on the transport of goods and tourist operation.

Therefore, at present landslides along the main thoroughfares are common problem to the hill people.

The Darjeeling Himalaya, a part of Eastern Himalaya lies between the Nepal Himalaya in the west and Bhutan Himalaya in the east. It is bounded towards north by the Sikkim Himalaya and towards south by Duar Plains of Ganga-Brahamputra Alluvium. The river Tista flowing north to south across Darjeeling Himalaya, exposes a full cross section of the eastern Himalaya. Darjeeling Himalayan ranges have suffered mass destruction due to its typical environment, characterized by well-foliated granite-gneissic and phyllitic rocks, huge amount of rainfall and temperature, higher degree of physical and chemical weathering and frequent neo-tectonic movements as well as unscientific settlement construction, severe deforestation, poor or non-maintenance of community drains etc. This has become the primary concern and therefore, landslide hazard zonation mapping and the discussion mapping techniques has become the target of this paper.

A landslide hazard zonation is a division of the land surface into areas, and the relative ranking of these areas according to degrees of actual or potential hazard from landslides on slopes [1]. This is a method to evaluate the risk where there is the potential for landslides. It is an important tool for designers, field engineers and geologists, to classify the land surface into zones of varying degree of hazards based on the estimated significance of causative factors that influence the stability [2]. The landslide hazard zonation map, in short called LHZ map, is a rapid technique of hazard assessment of the land surface [3].

LOCATION OF STUDY AREA

Along The present researcher has selected the main transport and arterial routes of Darjeeling Himalaya (Kalimpong district) running through West Bengal (Figure. 1) for searching the reasons behind such slope instability along transport and arterial sectors, their effects and for building a model to mitigate such hazard. The study area includes –

1. The Tista valley road or the National Highway 31A (now NH 10) from Sevok to Tista-bazar - The main route, connecting the North Bengal plains with hills of West Bengal and Sikkim

2. Roads between Kalimpong-Algarah, Algarah-Labha-Gorubathan this is an alternative route to Tista Valley road (National Highway 31A) connecting the North Bengal Plains to Kalimpong and Sikkim.

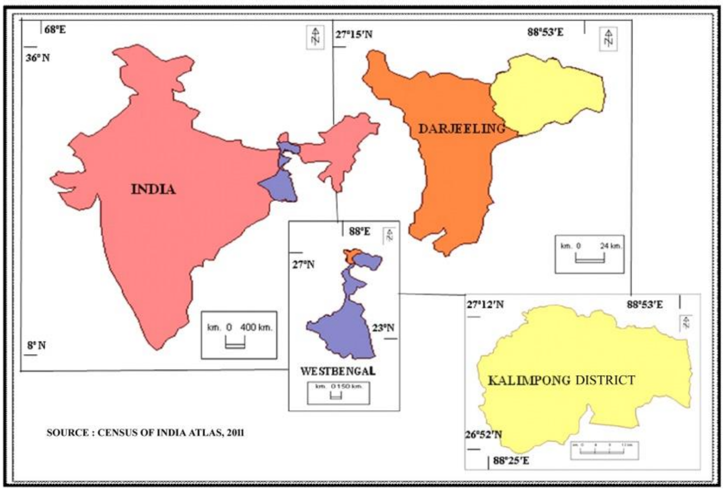


Fig-1: Location map of the study area

OBJECTIVES OF HAHARD MAPPING

- The main purpose of hazard mapping is to identify the landslide-affected area along transport arteries and their frequency as well as magnitude.
- Landslide Hazard Zonation (LHZ) map helps to identify the risk zones.
- To suggest appropriate measures for proper maintenance of the roads
- It works as a tool to create awareness in mitigating hazards.
- LHZ mapping is also very useful in planning purpose because it helps in the adoption of hazard mitigation strategy.
.

MATERIALS AND METHODS

The present study deals with landslide hazards that are occurring frequently and effecting severely in the study area. The methodology is based on the guidelines of the LHZ mapping [2,4]. LHZ map of the present study area has been prepared based on following ways:

- **Preparation of facet**

Facet map is prepared with the help of the topographical sheet (Map no. 78A/8, 78A/12, 78B/5 & 78B/9).

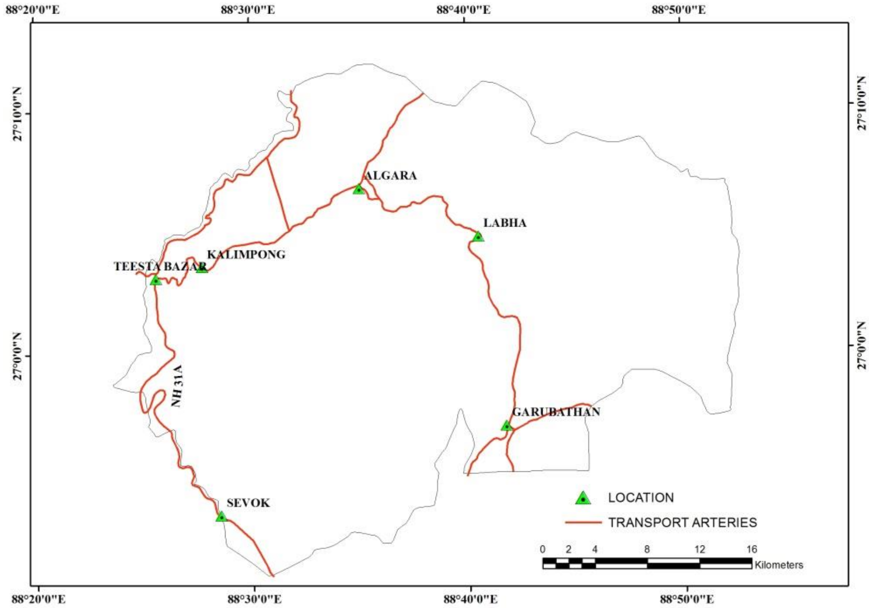
Preparation of facet map of the study area

Facet is a polygonal area of mountainous terrain, which has more or less similar characters of slope, showing consistent slope direction and inclination (Fig.2, 3 and 4). The slope facets are generally delimited by ridges breaks in slope, streams, spurs, gullies etc. The facet maps form the basis for the preparation of thematic maps in general and LHZ mapping in particular and individual facet is the smallest map able unit. In all 101 facets, including sub facets have been delineated from the study area based on visual interpretation of topographic maps.

Step for Preparation of Facet map along transport arteries of Kalimpong District.

Step I

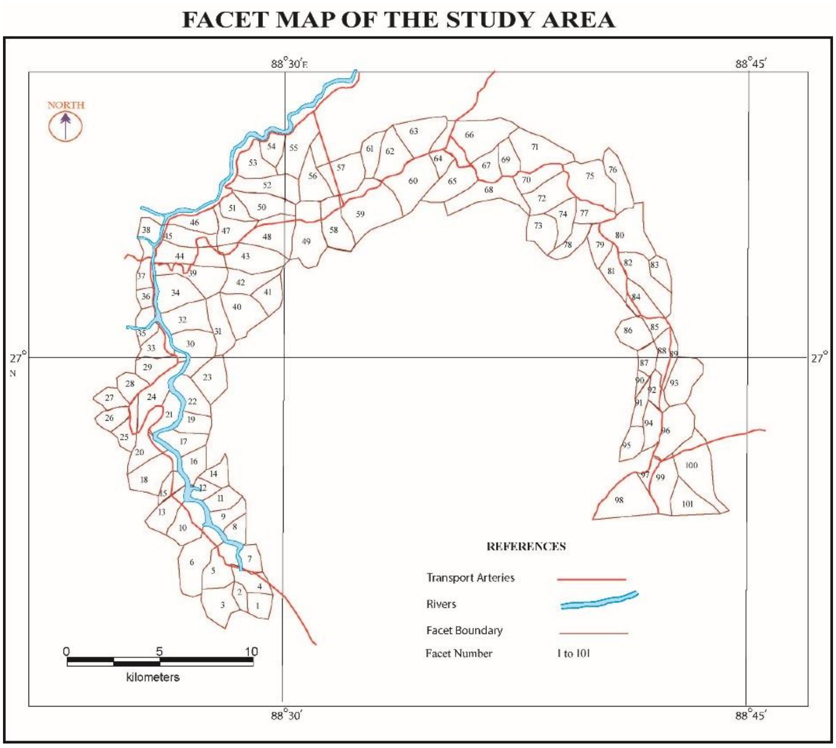
MAIN TRANSPORT ARTERIES OF KALIMPONG DISTRICT



Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9

Fig-2: Main transport arteries of Kalimpong district

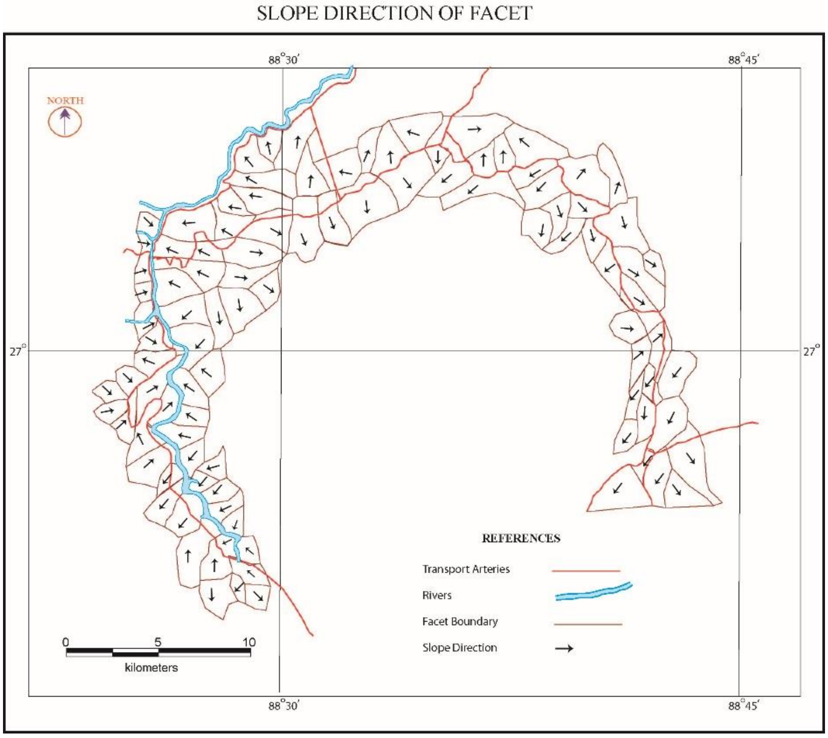
Step II



Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9.

Fig-3: Facet map of the study area

Step III



Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9

Fig-4: Slope direction of facet area

- **Landslide hazard evaluation factor (LHEF) rating scheme**

Estimate the varying degree of Landslide Hazard Evaluation Factor (LHEF) rating scheme. These LHEF rating scheme is a numerical weight age, governed by the major causative factors of the slope instability like lithology, structure, slope morphometry, relative relief, land use/ land cover and hydrological condition (see Table-1.). Each identified facet wise detail of all these contributory factors was prepared for assigning Landslide Hazard Evaluation Factor (LHEF) rating. The maximum rating of an individual contributory factor is shown in table-.2. The rating of these individual contributory factors varies with their varying nature up to their maximum rate in the facet area. Data of LHEF have been computed from interpretation of 1:50,000 Survey of India topographical maps, 1:50,000 geo coded LISS III satellite data existing geological maps and extensive fieldwork.

Table-1: LHEF ratings of different Causative Geo factors [4]

Geofactor	Description	Category		LHEF
Lithology	Type - 1 **	Type 1	Quartzite and limestone	0.2
	Highly weathered (4) :		Granite and Gabbro	0.3
	Moderately weathered (3) :		Gneiss	0.4
	Slightly weathered (2) :	Type 2	sandstone and minor beds of claystone	1.0
			Poorly cemented sandstone with minor clay / shale	1.3
	Type - 2**	Type 3	Slate and phyllite	1.2
	Highly weathered (1.5) :		Schist	1.3
	Moderately weathered (1.25) :		Shale with interbeded clayey and non-clayey	1.8
	Slightly weathered (1) :		Highly weathered shale, phyllite and schist	2.0
	Soil type	Older well-cemented fluvial fill material.		0.8
		Clayey soil with naturally from surfaces		1.0
		Sandy soil with naturally form surface (alluvial)		1.4
		Debris comprising mostly rock picees mixed with clayey sandy soil (colluvial) - ---- older well compacted		1.2
		----- Younger loose material		2.0
Structure	Relationship of parallelism between the slope and vulnerable discontinuity	>30`		0.20
		21` - 30`		0.25
		11` - 20`		0.30
		6` - 10`		0.40
		<5`		0.50
	Relationship of dip of vulnerable discontinuity and inclination of slope	>10`		0.3
		10` - 0`		0.5
		0`		0.8
		0`- (-10`)		1.0
		<-10`		0.2

Cont

	Dip of vulnerable discontinuity	<15`	0.20
		16`-25`	0.25
		26`-35`	0.30
		36`-45`	0.40
		>45`	0.50
	Depth of soil cover	<5m	0.65
		6-10m	0.85
		11-15m	1.30
		16-20m	2.0
		>20m	1.20
Slope	Escarpment/ cliff slope	>45`	2.0
	Steep slope	36`-45`	1.7
	Moderately steep slope	26`-35`	1.2
	Gentle slope	16`-25`	0.8
	Very gentle slope	<15`	0.5
Relative relief	< 100 m		0.3
	101 - 300 m		0.6
	> 300 m		1.0
Landuse and Landcover	Agricultural land/ populated flat land		0.6
	Thickly forest cover		0.85
	Moderately forest cover		1.20
	Sparsely forest cover		1.50
	Barren land		1.80
Hydrological condition	Flowing		1.0
	Dripping		0.8
	Wet		0.5
	Damp		0.2
	Dry		0

** Numerical values withen parenthesis are correction factor of weathering

- **Calculation of total estimated hazard (TEHD)**

Then calculate the Total Estimated Hazard (TEHD), which simply indicates the probabilities of instability of each facet. The Total Estimated Hazard (TEHD) of an individual facet has been calculated by adding the ratings of the individual causative factors obtained from the landslide hazard evaluation factor-rating scheme. Depending on the value obtained from the total estimated, hazard (see Table-3), each facet falls into their respective hazard classification.

Table-2: Maximum rating of individual causative factors [4]

Contributory Factors	Rating (Maximum)
Lithology	2.0
Structure	2.0
Slope Morphometry	2.0
Relative Relief	1.0
Landuse and Landcover	2.0
Hydrological condition	1.0
Total	10

- **Landslide hazard zonation**

Based on the distribution of TEHD values of each facet the landslide hazard zonation map has been prepared (see Table-4) and facilitates spatial classification of the study area into three zones viz. Moderate Hazard (MH), High Hazard (HH) and Very High Hazard (VHH)

Table-3: Landslide Hazard Zonation (LHZ) based TEHD [4]

Zone	TEHD Value	Description of Zones
I	5.1 - 6.0	Moderate Hazard (MH) Zone
II	6.1 - 7.5	High Hazard (HH) Zone
III	>7.5	Very High Hazard (VHH) Zone

Landslide hazard evaluating factors and their ratings of the study area

Lithology

The study area is a part of extra peninsula, made up of rocks of ages ranging from pre-Cambrian to Quaternary. The gneiss varies from a foliated granitoid rock composed of quartz, feldspar and biotite to more or less pure mica schist, and includes partly intrusive granite and partly metamorphosed beds of sedimentary origin. The Daling series covers a large area in the northeastern and western parts of the facet area. It consists of Phyllite, Gneiss and Schist.

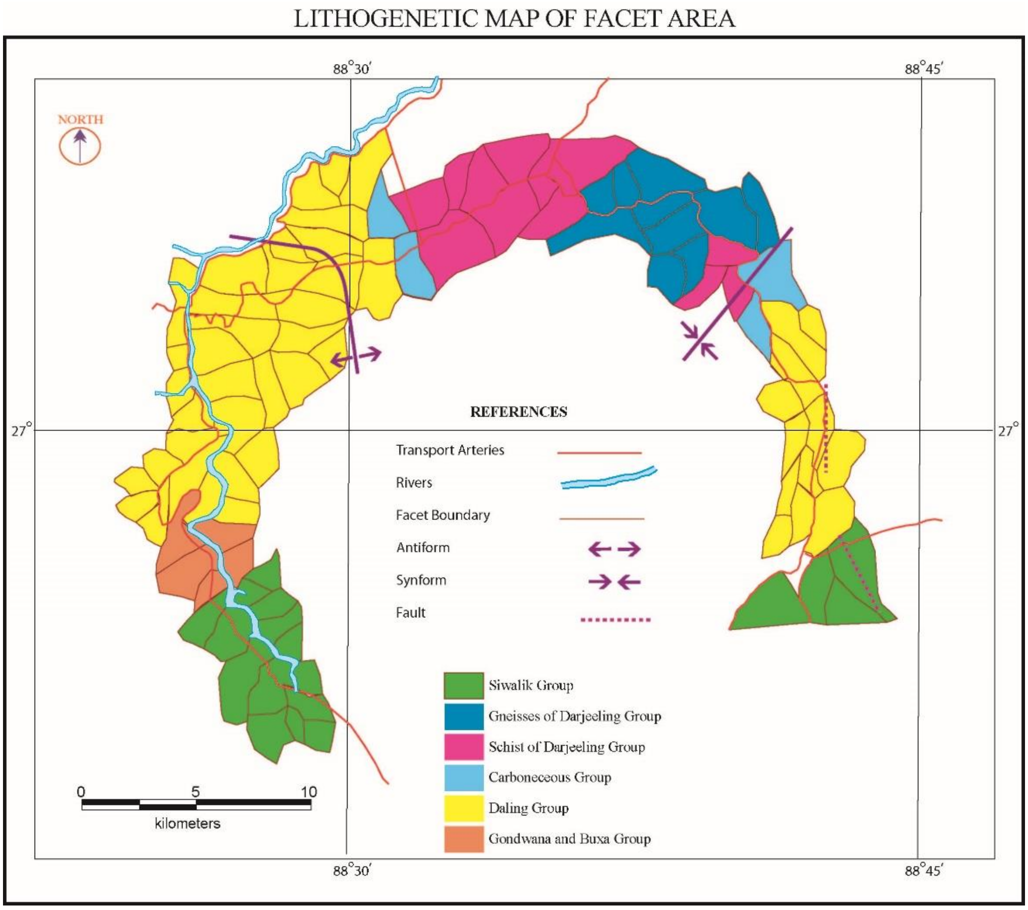


Fig-5: Lithological and structural condition of the facet area
Source: GSI Maps, (after B. Chatterjee, Geologist (SR), E.G Division E. R

The LHEF ratings of this group of rock are very high, that is 1.3 to 2.0 The Gondwana sedimentary beds crop out near the base of the hills and constitute with a narrow band between the Dalings and the Tertiaries. The Gondwana and Siwalik group of rock likes shale, slates etc cover the southern portion of the study area and the LHEF rating of this group of rock is ranges from 1.0 to 1.3 (Fig-.5).

Structure

Structures of the area include bedding planes, several set of joints, faults etc. The structural discontinuity in relation to the direction and inclination of slope has greater influence on the stability of slope. In Darjeeling Himalaya, most of the rockslides are caused by the presence of unfavorable dispositions of joints (for planar failures) or intersection of two joints (for wedge failures) vis-à-vis the slope aspect (or direction) and inclination. Thus, in areas of rocky slopes, the ratings according to the three structural geometric parameters as proposed in BIS guidelines are highly relevant.

Calculations of angular relationships between the dip direction/dip of joints (for planar failures) or the plunge direction/plunge of intersection of two joints (for wedge failures) and the direction/inclination of slope facets with rock exposures were carried out to assign different structural sub-ratings. The structural data (dip and strike of joints) were collected from available geological maps and recent field data and zones of possible planar and wedge failures within the rocky areas were assessed. The LHEF rating is ranging from 1.35 to 1.75 in the northern portion of the facet area. (Fig.-5). Faults structures are found in the Darjeeling, Daling and Siwalik group of rock in the western portion of the study area. Anticlines and synclines structure are found in northern portion of the study area.

Relative relief

Relative Relief map represents the difference between the maximum and minimum heights within an individual facet. It shows the major breaks in the slopes of the area. Relief map of the study area has been prepared from the slope facet map by subtracting the lowest contour value from the highest contour value in a facet. The entire area has been divided into three categories of Relative relief i.e.
i) Low (<100 m) ii) Medium (101- 300 m) and iii) High (>300 m).

The relative relief of the study area is very high that the maximum portion of the study is >300 m.

Therefore, the LHEF rating of the entire area is 1.0 (Fig.-6).

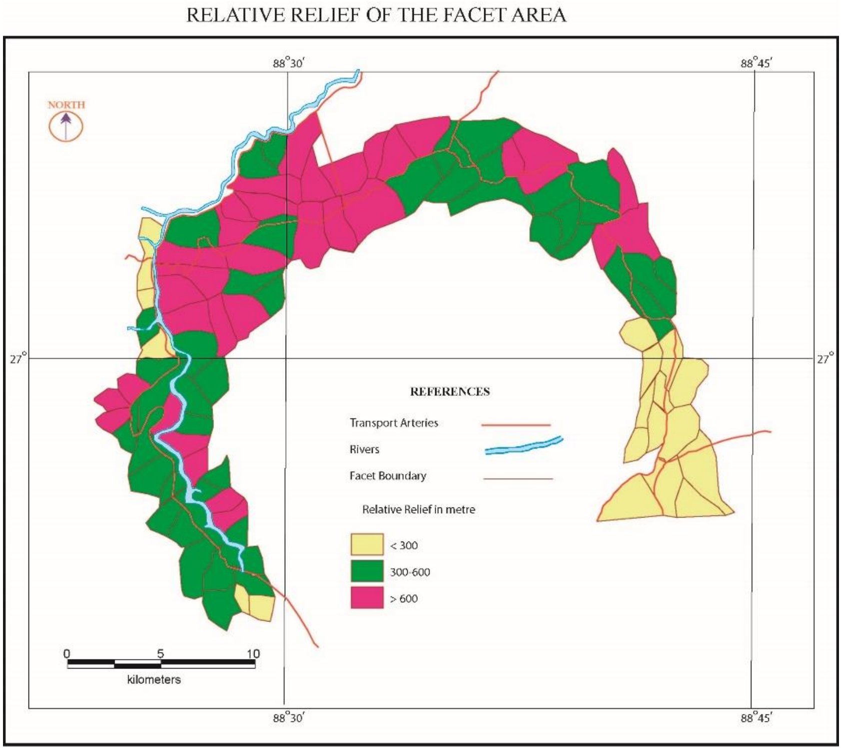


Fig-6: Relative relief map of the facet area
Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9

Slope morphometry

Five categories of slope morphometry such as escarpment / cliff slope, steep slope, moderately steep slope, gentle slope and very gentle slope are used depending on their slope angle in a particular facet. Since the slope angle is considered as an important geo-environmental parameter inducing slope instability. LHEF value 2 (maximum) has assigned for it. Western portion along the Teesta River and the northern portion of the study area are characterized by moderate steep to steep slope (that is 26° to 45°), whereas the LHEF rating ranges from 1.2 to 1.7. Gentle slope (below 25°) occupied the Eastern and central portion of the study area, where the LHEF rating is 0.8 (Fig.-7).

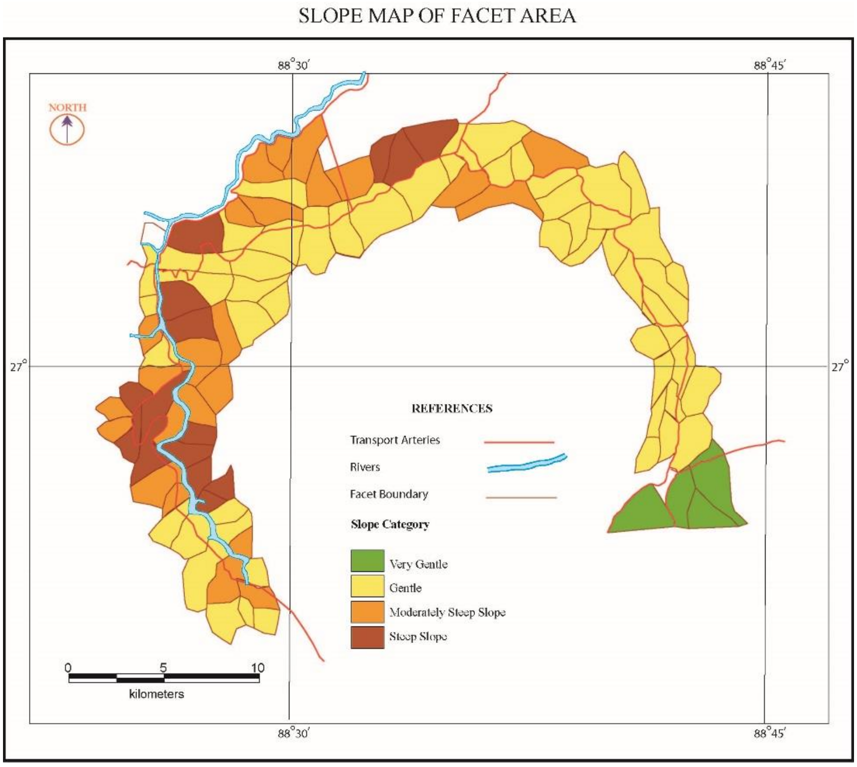


Fig-7: Slope map of the facet area
Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9

Landuse and Land cover

Land-use/Land-cover map of the project area has been prepared on basis of visual interpretation of LISS III with field check. Based on land-use/ land cover pattern, the area has been divided into five categories such as agriculture land/ populated flat land, thickly covered with forest, moderately covered with forest, sparsely forest cover and Jhum/ Terrace cultivation/ Barren. Land-use pattern is variable in this area. Thickly forest cover occupies in the western and northwestern portion of the study area, where the LHEF rating is 0.85. Agricultural land and populated flat land occupy the northwestern and eastern portion of the study area, where the LHEF rating is 0.6 and some pockets are covered by sparse forest of the study area and the LHEF rating of these portions is 1.5 (Fig-8).

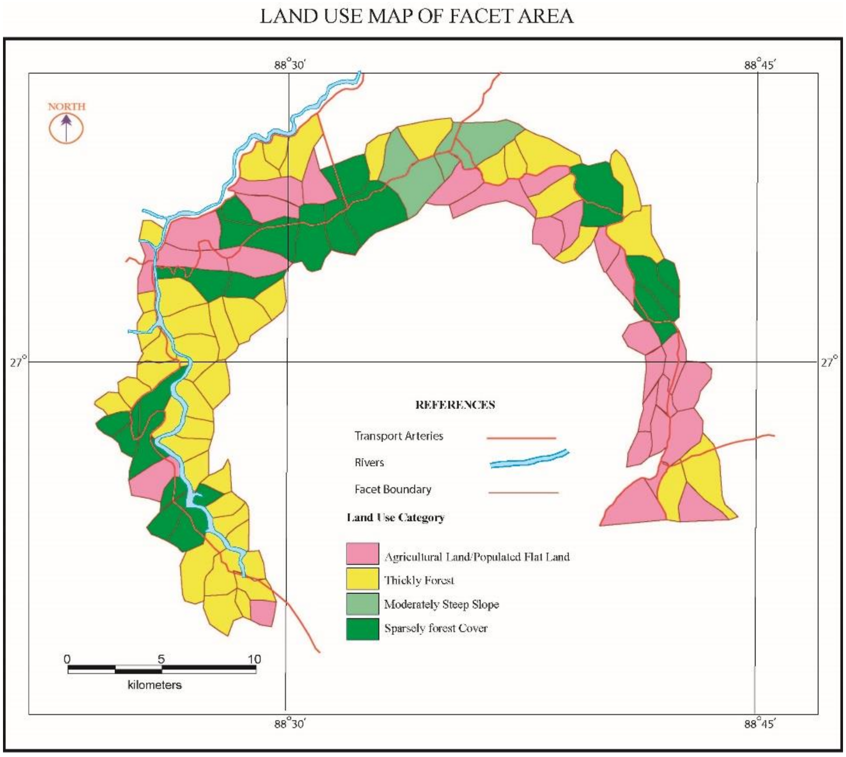


Fig-8: Land use map of the facet area

Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9., Natmo Map & other Govt. agencies

Hydrological condition

Five categories of hydrological condition in LHEF rating scheme [4, 4] such as flowing, dripping, wet, damp and dry are used assigning with their respective rating. The maximum portion of the facet area is wet so the LHEF rating is 0.5 and some pockets of the overall facet area is dripping condition whereas the LHEF rating is 0.8 (Fig-9).

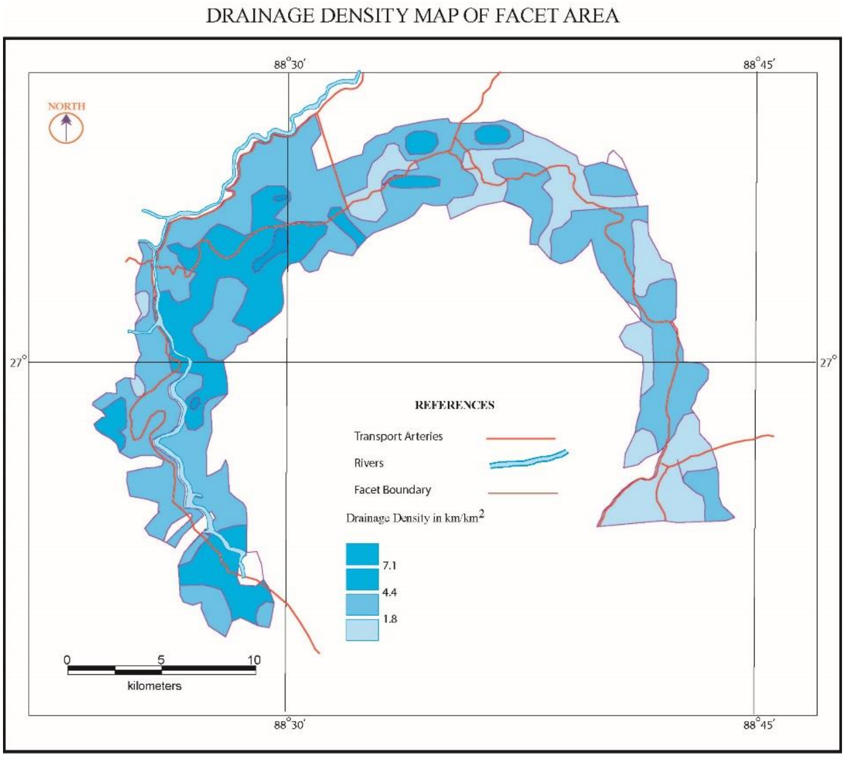


Fig-9: Drainage Density map of the facet area

Source: SOI Toposheet Map No. 78A/8, 78A/12, 78B/5 & 78B/9.

Events of landslides in the study area

Kalimpong District of Darjeeling Himalaya has witnessed several prominent landslide events; some of which are mentioned below in Table no 4.

Table- 4: Major events of landslips in Kalimpong District

Location of event	Time of occurrence	Loss/Damage	Triggering factor
Kalimpong town	January, 1934	Loss of property and land	Reported to be linked with Bihar-Nepal earthquake of 1934
Kalimpong town	June,1950	Loss of property and life, hundreds became homeless; Siliguri-Kalimpong Railway line was closed for ever due to incessant instability along steep slope	Caused due to unprecedented continuous rainfall of 834.10mm in 3 days
Kalimpong,the entire stretch of NH-31A	October, 1968	Total stretch of NH-31A either washed away or damaged; road closed and Tista bazaar bridges was washed away.	due to incessant rainfall of 1121.4mm within 4 days
Kalimpong, Lava paparkhati area	September, 1980	Several people lost their life and loss of property.	Due to incessant rainfall of 299.1mm in 2 days
Kalimpong town, Lava sector and NH-31A stretch	September, 1991	Huge land and property got damaged	due to incessant rainfall of 462.5mm in 2 days
Kalimpong, Lava paparkhati area	July, 1998	Severe damage and road blockades	300 – 600 mm cumulative rainfall in 2/3 days caused these slides
Swatijhora and Lukuvir slides	July, 2003	Loss of property and land	A concentrated rainfall of over 300 mm during a period of 48 hours
Kalijhora Lukuvir and Baluwakhani slides	August, 2009	Loss of property and land	Torrential rain for a period of more than 70 hours and flash flood
14 mile landslide	June, 2010	Loss of property and land	Torrential rain of 122 mm from 16 to 20 june,2010
Tista Bazar – sevok section of N H-31A	September, 2011	Total stretch of NH-31A was or damaged and washed away.	Reported to be linked with earthquake of Sikkim, 2011
Slides: Kalijhora, Swetijhora, Lukuvir, 14mile, Baluwakhani, Lava and paperkhati	July, 2015	Severe damage and road blockades mainly along NH -31A; most affected terrain is Kalimpong and its surroundings	Torrential rainfall and reported to be linked with earthquake of Sikkim and North Bengal, 2015

Table -5: Causative factors of each facet

Facet	Lithology	Structure	Slope	Relief	Landuse	Hydrology	TEHD	HAZARD CATEGORY
1	1.3	1.35	0.8	0.6	0.85	0.5	5.4	MH
2	1.3	1.35	0.8	0.6	0.85	0.5	5.4	MH
3	1.3	1.35	0.8	1.0	0.85	0.5	5.8	MH
4	1.3	1.35	1.2	1.0	0.85	0.5	6.2	HH
5	1.3	1.35	1.2	1.0	0.85	0.5	6.2	HH
6	1.3	1.35	0.8	1.0	0.85	0.5	5.8	MH
7	1.3	1.35	0.8	1.0	0.85	0.5	5.8	MH
8	1.3	1.35	1.2	1.0	0.85	0.5	6.2	HH
9	1.8	1.35	1.2	1.0	0.85	0.5	6.7	HH
10	1.8	1.35	0.8	1.0	1.5	0.5	6.95	HH
11	1.8	1.35	1.2	1.0	0.85	0.5	6.7	HH
12	2.0	1.35	1.2	1.0	1.5	0.2	7.55	VH
13	2.0	1.35	0.8	1.0	1.5	0.5	7.15	HH
14	2.0	1.75	1.7	1.0	0.85	0.2	7.5	HH
15	2.0	1.75	1.2	1.0	1.5	0.8	8.25	VH
16	2.0	1.75	1.7	1.0	0.85	0.5	7.8	VH
17	2.0	1.35	1.7	1.0	0.85	0.5	7.4	HH
18	2.0	1.35	1.2	1.0	0.6	0.8	6.95	HH
19	2.0	1.35	1.7	1.0	0.85	0.5	7.75	VH
20	2.0	1.75	1.7	1.0	1.5	0.5	8.45	VH
21	2.0	1.35	1.2	1.0	1.5	0.2	7.25	HH
22	2.0	1.35	1.2	1.0	0.85	0.5	6.9	HH
23	2.0	1.35	1.2	1.0	0.85	0.5	6.9	HH
24	2.0	1.75	1.7	1.0	1.5	0.5	8.45	VH
25	2.0	1.75	1.7	1.0	1.5	0.5	8.45	VH
26	2.0	1.75	1.2	1.0	0.85	0.5	7.3	HH
27	2.0	1.35	1.2	1.0	0.85	0.5	7.2	HH
28	2.0	1.35	1.7	1.0	0.85	0.5	7.4	HH
29	2.0	1.35	1.2	1.0	0.85	0.5	6.9	HH
30	2.0	1.35	1.2	1.0	0.85	0.5	6.9	HH
31	2.0	1.35	1.2	1.0	0.85	0.5	6.9	HH
32	2.0	1.35	1.7	1.0	0.85	0.5	6.9	HH
33	2.0	1.35	0.8	0.6	0.85	0.5	6.1	HH
34	2.0	1.35	1.7	1.0	0.85	0.5	6.5	HH
35	2.0	1.35	1.2	1.0	0.85	0.5	6.9	HH
36	2.0	1.35	0.8	0.6	0.6	0.5	5.85	MH
37	2.0	1.35	0.8	0.6	0.6	0.5	5.85	MH
38	2.0	1.35	0.8	0.6	0.85	0.5	6.1	HH
39	2.0	1.35	0.8	1.0	1.5	0.5	7.15	HH
40	2.0	1.35	0.8	1.0	0.85	0.5	6.5	HH
41	2.0	1.35	0.8	1.0	0.85	0.5	6.5	HH
42	2.0	1.35	0.8	1.0	1.5	0.5	7.15	HH
43	2.0	1.35	0.8	1.0	0.6	0.5	6.25	HH
44	2.0	1.35	0.8	1.0	0.6	0.5	6.25	HH
45	2.0	1.35	0.8	1.0	0.6	0.5	6.25	HH
46	2.0	1.35	1.7	1.0	0.6	0.5	6.65	HH
47	2.0	1.35	0.8	1.0	1.5	0.5	7.15	HH
48	2.0	1.35	0.8	1.0	1.5	0.5	7.15	HH
49	2.0	1.35	0.8	1.0	1.5	0.5	7.15	HH
50	2.0	1.35	1.2	1.0	1.5	0.5	7.15	HH
51	2.0	1.35	1.2	1.0	0.6	0.5	6.25	HH

Facet	Lithology	Structure	Slope	Relief	Landuse	Hydrology	TEHD	HAZARD CATEGORY
52	2.0	1.35	0.8	1.0	0.6	0.5	6.25	HH
53	2.0	1.35	1.2	1.0	0.85	0.5	6.5	HH
54	2.0	1.35	1.2	1.0	0.85	0.5	6.5	HH
55	2.0	1.35	1.2	1.0	0.85	0.5	6.5	HH
56	1.6	1.35	1.2	1.0	0.6	0.5	5.85	MH
57	1.6	1.75	1.2	1.0	1.5	0.8	7.85	VHH
58	1.6	1.75	0.8	1.0	1.5	0.8	7.45	HH
59	2.0	1.75	0.8	1.0	1.5	0.8	7.85	VHH
60	2.0	1.75	0.8	1.0	1.2	0.8	7.55	VHH
61	2.0	1.35	1.7	1.0	0.85	0.8	7.2	HH
62	2.0	1.35	1.7	1.0	1.2	0.8	7.15	HH
63	2.0	1.35	1.7	1.0	0.85	0.8	7.2	HH
64	1.6	1.35	0.8	1.0	1.2	0.8	6.75	HH
65	1.6	1.35	1.2	1.0	0.6	0.8	6.55	HH
66	1.6	1.35	0.8	1.0	1.2	0.8	6.75	HH
67	1.6	1.35	0.8	1.0	0.85	0.8	6.4	HH
68	1.6	1.35	1.2	1.0	0.6	0.8	6.55	HH
69	1.6	1.35	1.2	1.0	0.85	0.8	6.8	HH
70	1.6	1.75	0.8	1.0	0.6	0.5	6.25	HH
71	1.6	1.75	1.2	1.0	0.85	0.5	6.9	HH
72	1.6	1.75	0.8	1.0	0.85	0.5	6.5	HH
73	1.6	1.75	0.8	1.0	0.6	0.5	6.25	HH
74	1.6	1.75	0.8	1.0	0.6	0.5	6.25	HH
75	1.6	1.75	0.8	1.0	1.5	0.5	7.15	HH
76	1.6	1.35	0.8	1.0	0.85	0.5	6.4	HH
77	1.6	1.75	0.8	1.0	1.5	0.5	7.15	HH
78	1.6	1.35	0.8	1.0	0.85	0.5	6.1	HH
79	1.6	1.35	0.8	1.0	0.6	0.5	5.85	MH
80	1.6	1.35	0.8	1.0	0.85	0.5	6.1	HH
81	2.0	1.75	0.8	1.0	0.6	0.5	6.65	HH
82	2.0	1.75	0.8	1.0	1.5	0.8	7.85	VHH
83	2.0	1.75	0.8	1.0	1.5	0.8	7.85	VHH
84	2.0	1.75	0.8	1.0	1.5	0.8	7.85	VHH
85	2.0	1.75	0.8	06	1.5	0.8	7.45	HH
86	1.6	1.75	0.8	0.6	0.6	0.8	6.15	HH
87	1.6	1.75	0.8	0.6	0.6	0.2	5.35	MH
88	1.6	1.75	0.8	0.6	0.6	0.2	5.35	MH
89	1.6	1.75	0.8	0.6	0.6	0.2	5.35	MH
90	1.6	1.35	0.8	0.6	0.6	0.2	5.55	MH
91	2.0	1.35	0.8	0.6	0.6	0.2	5.95	MH
92	2.0	1.35	0.8	0.6	0.6	0.2	5.55	MH
93	2.0	1.35	0.8	0.6	0.6	0.5	5.85	MH
94	1.3	1.35	0.8	0.6	0.6	0.5	5.15	MH
95	1.3	1.35	0.8	0.6	0.6	0.2	4.85	MH
96	1.3	1.35	0.8	0.6	0.6	0.2	4.85	MH
97	1.3	1.35	0.8	0.3	0.6	0.2	4.55	MH
98	1.3	1.35	0.5	0.3	0.6	0.2	4.5	MH
99	1.3	1.35	0.5	0.3	0.85	0.2	4.5	MH
100	1.3	1.35	0.5	1.0	0.6	0.2	4.95	MH
101	1.3	1.35	0.5	0.3	0.85	0.2	4.5	MH

RESULTS AND DISCUSSION

There are several causative factors of slope instability like lithology, structure, slope morphometry, relative relief, land use/ land cover and hydrological condition of the study area, which are discussed in detail and interpreted, with the help of their respective maps. From the discussion and interpretation of these causative factors in and around 101 facets and their respective LHEF rating are determined for preparation of hazard zonation map (see table-5). Finally, from the Landslide Hazard Zonation Map of the study area (Fig.10), it indicates that the maximum portion of the facet area (western, northern and northeastern) falls under high hazard zone, i.e. along the Teesta River (sevok to Teesta bazaar), Kalimpong town area, and Kalimpong Algara- Labha sector. Kalijhora, Swetijhra, Algara and Labha spot of the facet area are characterized by Very high hazard zone. Southwestern and southeastern (Garubathan) portions of the study area fall under medium hazard zone.

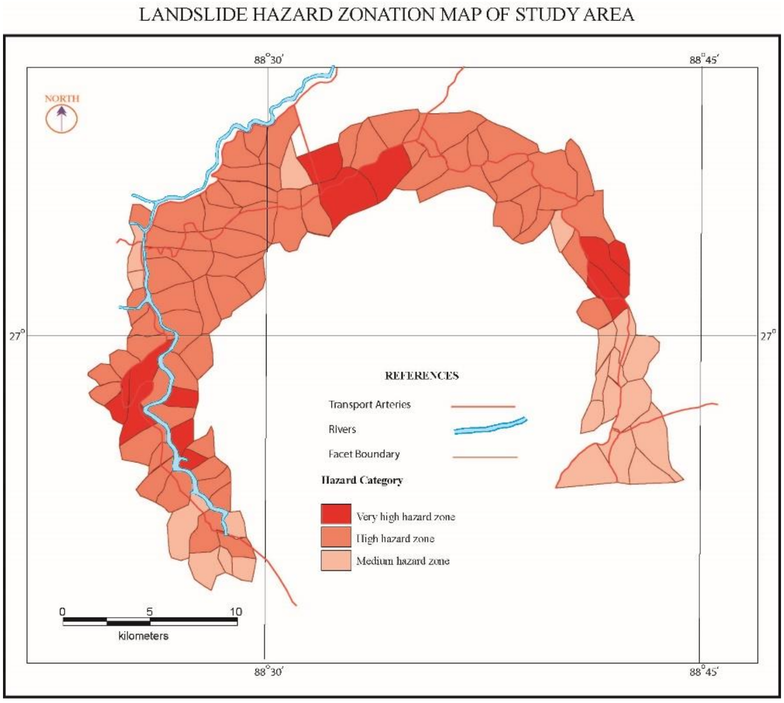


Fig-10: Landslide Hazard Zonation map of the facet area

Based on SOI Toposheet Map No 78A/8, 78A/12, 78B/5 & 78B/9., LAND SAT IMAGE, GSI Map, Natmo Map and other Govt. agencies.

CONCLUSION

The present study deals with the preparation of landslide hazard zonation mapping along transport arteries of Kalimpong District. Results from the studies highlight the Very High and High landslide hazard zones followed by Medium hazard zone in the study area. LHZ map will be useful for undertaking proper management techniques for future development activities such as widening or shifting of roads, new road set up, tunneling etc. Therefore, this is the high time to take necessary steps than to be confined within the discussion of the bleak view of the landslide hazards occurring over this region.

REFERENCES

1. Varnes DJ. Landslide hazard zonation: a review of principles and practice. 1984.
2. Anbalagan R. Landslide hazard evaluation and zonation mapping in mountainous terrain. Engineering geology. 1992 Jul 1;32(4):269-77.
3. Gupta RP, Joshi BC. Landslide hazard zoning using the GIS approach—a case study from the Ramganga catchment, Himalayas. Engineering geology. 1990 Feb 1;28(1-2):119-31.
4. Bureau of Indian Standards (BIS-1998): Preparation of Landslide Hazard Zonation Maps in Mountainous Terrains – Guidelines.1998.