ZONATION MAPPING TECHNIQUES OF THE LANDSLIDE HAZARD IN DARJEELING HILLS, WEST BENGAL, INDIA

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ABSTRACT

Darjeeling hill in West Bengal, India is a place where landslides and related phenomena bring about considerable distress in the rainy season every year. Of late, the incidence of landslide occurrence has increased many folds significantly with the gradual anthropogenic abuse of slopes by human being following rapid agglomeration of population centered on profitable hill tourism and ordered government after independence. This situation has resulted varied magnitudes of landslide hazard zones in different parts of the hills. Therefore, landslide hazard zonation mapping becomes indispensable for this region since it can help the planner to identify the risks of damage and simultaneously help to take appropriate management for the hazard. With this view in mind the present paper takes an attempt to undertake the work of landslide hazard zonation mapping of Darjeeling hills.

Key Words: *Anthropogenic; landslide hazard; zonation mapping; risk of damage; management; hazard magnitude; mapping technique.*

INTRODUCTION

When an area is exposed to hazard, e.g. landslide, mapping of hazard helps the planning team to locate and analyze all the degrees of vulnerability and risk. By facilitating the interpretation of hazard information, it increases the likelihood that the information will be used in the decision-making process, either in the planning of new development projects or by incorporating hazard reduction techniques into existing developments. Most effective use of hazard information is achieved when maps clearly depict the likelihood of occurrence, location, and severity of the hazard (Kockelman, 1979). Thus, hazard mapping can play a role of great value.

The Darjeeling hills which comprise the three hill subdivisions, viz. Darjeeling Sadar, Kurseong and Kalimpong subdivisions have been subjected to landslide hazards and similar phenomena since time immemorial. The landslides in the earlier time e.g. in the pre-independence period used to take place mostly in the areas where the setup of the physical environment of the hill subdivisions was weak being associated with less strong and more disturbed geological formations, precipitous slopes with thin soil and low vegetation cover, the characteristic soil parameters responsible for slide etc. These are the natural terrain parameters which play role in slope failure (Hays, 1981; Kitutu, et.al. 2009; Sarkar et. al., 2010). But the severity and the frequency of the landslide hazard have been increased significantly after independence with rapid agglomeration of population following ordered government and profitable hill tourism in the panoramic sites of the Darjeeling hills. In recent time, a great amount of landslides are caused due to the over exercise on nature by human being and thus, there has been a rapid acceleration of landslide phenomena over this region due to anthropogenic abuse like unscientific settlement construction, severe deforestation, overloaded cargo (more than 80 ton trucks etc) induced tremor, poor maintenance of tea garden areas, dumping of garbage behind the settled buildings, poor or non-maintenance of community drains etc (Bhattacharya, 1998, 1999, 2002 and 2010, Ghosh et. al., 2009). This has become the primary concern and therefore, landslide hazard zonation mapping and the discussion mapping techniques has become the target of this paper.

AREA OF STUDY

The study area as mentioned is the three hill subdivisions, which constitutes the administrative boundary of the Darjeeling hills although some parts of the Siliguri subdivision come under the hilly terrain but that has been excluded. The exact areal delineation of the Darjeeling hills ranges from 26°46'17.45" to 27°12'20.48" N latitudes and 87°59'35.41" to 88°52'59.22" E longitudes covering an area of 2222 km^2 (Figure 1).

OBJECTIVES AND BENEFITS OF HAZARD MAPPING

1. The main purpose of hazard mapping is to gather together in one map the different magnitudes of hazard-related information (e.g. landslide) for a study area to convey a composite picture of the hazard of varying magnitude, frequency, and area of effect.
2. It works as a tool to create awareness in mitigating hazards. It helps in the comprehensive analysis for assessing vulnerability and risk.
3. Hazard zonation mapping is also very useful in planning purpose because it helps in the adoption of hazard mitigation strategy, emergency preparedness planning, allocation of disaster planning funds according to the magnitudes of hazard etc.

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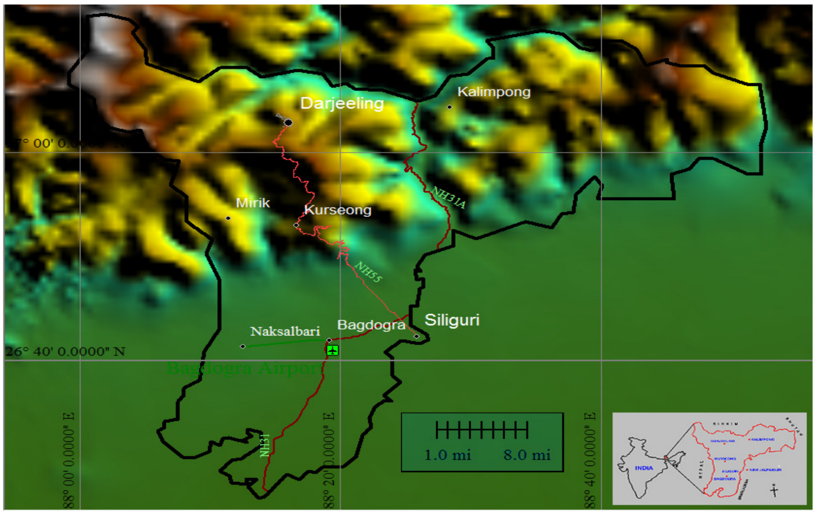


Figure 1: Location map of Darjeeling Hills

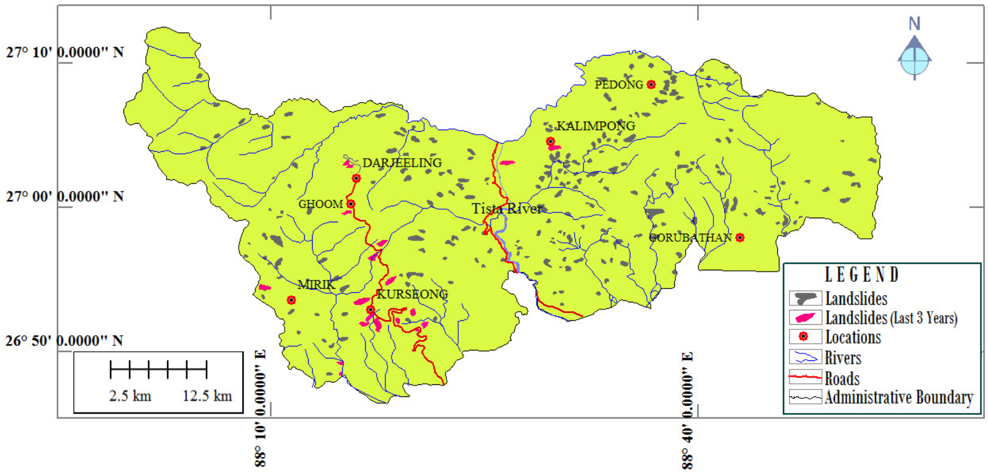
MATERIALS AND METHODS FOR MAPPING

The preparation of hazard map depends on many prerequisites and technical considerations (Pandey et. al. 2008). To discuss about the techniques of hazard zonation mapping, a workout example of the landslide hazard zonation of the Darjeeling hills has been incorporated which has been based on the preparation of base map from SOI Topographical sheets, Translated Information like past occurrences of landslides collected from Aerial Photographs, satellite Imageries, data and information from secondary sources, Field Survey and view ground truthing and application of Quantitative Techniques for preparation of landslide hazard zone map. The elaborated discussion of the techniques for mapping is as follows:

i. Base Map

For preparation of hazard zonation map, the first prerequisite is obtaining or creating a base map upon which to place the information regarding hazard. This initial map serves as an index. Base map can be created from scratch, but it is a difficult and time-consuming task. Therefore, alternative way is to use an existing map or controlled photograph as a base. An adequate base map must be planimetric, that is, a representation of information on a plane in true geographic relationship and with measurable horizontal distances; and must have sufficient geographic reference information to orient the user to the location of the hazard. The top of a map is usually oriented to the north, but not always. Hence, a 'north arrow', scale and area covered showing national boundaries and major cities on each map sheet are mandatory. Display of highways and rivers; even local street names and building site boundaries can be more useful (URL 1). Figure 2, is an example of planimetric map, and has sufficient reference information. Two types of information have been incorporated regarding landslide occurrence- the landslides that occurred before three years with deep gray color and the landslides that occurred during last three years with pink colour. The data of the landslides that occurred before 3 years have been collected from various sources like website (URL 2) , from aerial photographs: 784-A/20-5 to 11, 784-A/21-5 to 10, 784-A/22-3 to 8, 784-A/23-5 to 10, 784-A/24-5 and Google image with necessary modifications and landslide during 3 years in pink color by personal field survey with the help of GPS and survey instruments. Many occurrences of the landslides for the past three years shown in the base map undoubtedly prove that how landslides have been accelerated in the Darjeeling hills.

Figure 2: Base map showing Landslides in Darjeeling Hills



a. Scale and Coverage

Map scale is the measure of reduction in size from the actual environment to that portrayed on the map. Hazard zonation mapping work can be started with a scale of 1:500,000 or 1cm = 5km. Larger scales are more common for regional development planning (1:50,000), and community development plans (1:24,000 through 1:12,000). The scale selected will depend upon the map's purpose. There are no best scales; only more appropriate ones to coincide with planning requirements (URL 1).

For landslide hazard zonation, the scale of the base map showing landslides in Darjeeling hills has been used 1:50,000 i.e. 2 cm=1 km so that almost all the landslide scars can be covered within the map of the three subdivisions of the Darjeeling hills. The hazard zone map is also prepared and drawn on the same scale.

b. Types of Symbols

Symbols are selected for their legibility and clarity. The symbols used in the base map (Figure 2) are deep gray and pink coloured landslide scars, locations, roads, rivers etc. and colours in the hazard map are to explain various magnitudes of landslide hazards of the Darjeeling hills (Figure 3).

ii. Translated Information

Much hazard information will be in the form of scientific investigations into the potentially hazardous event and observations of the impact of past events (Du Bois, 1985), such as landslide inventories. It is often in forms other than maps. A compact view of the inventory of the landslides occurred last 3 years has been given in the table 1 as a token example. In preparing the landslide hazard zonation map of the Darjeeling hills, many translated information from personal level and various agencies have been incorporated to cross-verify the present effectiveness of the landslide scars available in the images and aerial photographs and accordingly things have been rectified to increase accuracy. Finally the rectified information with further ground truthing (wherever possible) are "translated" and placed on landslide hazard maps for planners and decision-makers. Successful translation must be in a format that a planning team can understand.

iii. Sources and Compiling Information

There is a vast array of sources of hazard information, including various public and private libraries, offices and reference centers at national, regional, and community levels. Huge information is available from Internet sources too. Hazard information are extracted or inferred from photographic, topographic, geologic, hydrologic, climatologic, and soils information already prepared. Hazard information may also be obtained from remote sensing data. The information of the landslide hazard of the Darjeeling hills have been obtained from the aerial photographs and images and cross verified with the available information from various documents collected from different agencies and internet sources along with ground truthing done by field survey and view.

iv. Field Survey and view

Field survey and view are the most reliable way for justifying the existence of the hazard phenomena available from other sources. Ground truthing finally proves whether things exist or not. Therefore, field investigation play a very important role in identifying hazards and proceed to the next stage. An intensive field survey has been done in different phases to obtain the real picture of the landslide occurrence over different parts of the Darjeeling hills to rectify the mismatch between information collected and the information viewed.

Table 1: Inventory of the landslides occurred last 3 years

Name	Altitude in metre	Latitude	Longitude	Shape	Loss of life	Damages
Frimal Village	2050	27° 03.33'N	88°15.32'E	Semi-rectangular	-	22 houses (most are more than one story) have been destroyed fully
Haridash - Hatta	2044	27° 0.68'N	88°15.69'E	Funnel	7	1 house partially damaged and tea garden severely damaged
Ghum (Immanual Church)	2236	27° 00'N	88°15.60'E	Triangular	-	Road severely damaged
Sonada	1960	26° 56.55'N	88°16.78'E	Rectangular	-	Many telephone and electric posts damaged and connection disrupted
Aurangley Near Tung	1767	26° 56.46'N	88°17.94'E	Funnel		2 houses smashed and many houses damaged.
Sukhipull	1581	26° 54'N	88°17.15'E	Funnel		-
Sirubari 2 (Gourisankar)	1436	26° 52.36'N	88°16.98'E	Elongated	2	Tea garden and some houses at smashed and damaged
Jungpana	1235	26° 52.93'N	88° 18.27'E	Diamond	-	Lower level houses damaged
Below Mahanadi	1187	26° 52.64'N	88° 18.64'E	Elongated	-	Road severely damaged
Banduke Gaon	1229	26° 52.90'N	88° 19.26'E	Funnel		Houses and teagarden damaged
Near Tindharia Market	792	26° 50.85'N	88° 19.72'E	Funnel		Road Damaged
Above Panighata Road	320	26° 48.46' N	88° 14.86' E	Triangular	-	Road Damaged

Surveyed by Author

COMPILING INFORMATION ON HAZARD ZONE MAP

This is associated with multiple tasks with much care and accuracy. These tasks are as follows:

- Evaluating the uniformity, accuracy, and completeness of such information-areal coverage, detail, content, elements etc.
- Quantitatively assess the occurrence magnitude in a clear and convenient way.

For preparation of the landslide hazard zonation map the number of landslide occurrences per 5 km^2 has been fixed up as standard measure and the whole region has been divided into different groups of magnitude of landslide occurrences. The frequency study of all these zones have also been carried out by using the following equation:

$L_f = \sum n / As$.....................(1)

Where

L_f = Landslide frequency; $\sum n$ = Number of total landslide occurrence;

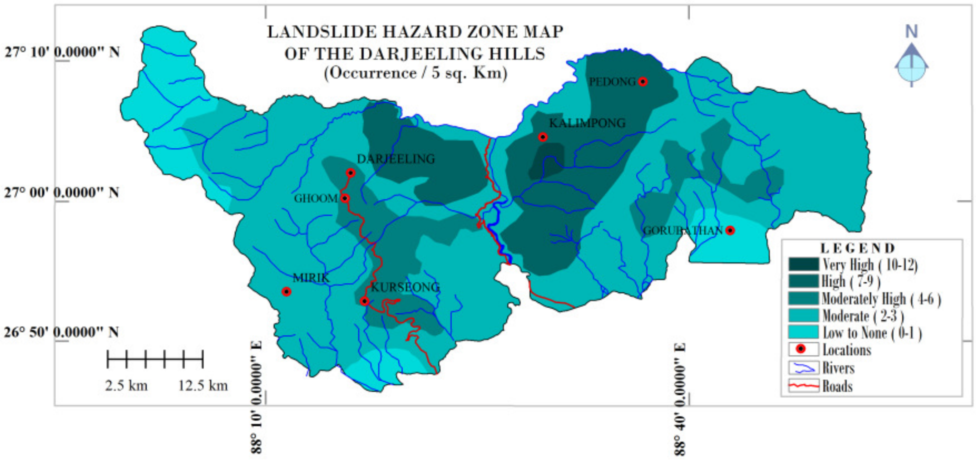
As = Area specified i.e. 5 km^2.

Figure 3 explains various *landslide hazard zones* which are described below:

Very high zone of landslide hazard

This zone is confined in a small patch on the northern central part of the Darjeeling hills falling in Kalimpong subdivision where 10 to 12 landslides occur in 5 km^2 area. Very high frequency of occurrence, >2 landslide/1km^2 is associated with this zone. 14.628 km^2 area of the Darjeeling hills falls within this zone.

Figure 3:Landslide hazard zone map of the Darjeeling Hills



This zone is most unsafe for human habitation and thus can be distinguished as prohibitive zone from the viewpoint of landslide occurrence.

High zone of landslide hazard

This zone encompasses two separate areas, one covering Darjeeling Sadar subdivision on the right side of the Tista river extending along northwest-southeast and another in the Kalimpong subdivision on the left bank of the Tista river having wider extension from northeast-southwest in the Darjeeling hills where 7 to 9 landslides occur in 5 km^2 area. This zone has a frequency of >1 landslides/1km^2 which indicates that the areas suffer from high landslide hazard and therefore, can be explained as highly restrictive zone from the view point of landslide occurrence. The areal coverage of this magnitude zone in the Darjeeling Hills is 410.5 km^2.

Moderately High zone of landslide hazard

Moderately high zone of landslide occurrence is found in two areas extending along northwest-southeast below the high zone in Darjeeling Sadar and Kurseong subdivisions as well as east-westward on the southeast of high landslide zone in the Kalimpong subdivision. This zone represents at least one landslide frequent in most of the parts per 1km^2. So, this zone can also be explained as restrictive zones for human habitation from the viewpoint of landslide occurrence. The areal coverage of this zone is 234.49 km^2 in the Darjeeling hills.

Moderate Zone of landslide hazard

Moderate zone encompasses the largest area of the Darjeeling hills covering all the hill subdivisions where there remains a chance of at least one landslide/km^2 as frequency of landslide occurrence ranges from 0.4-0.6 i.e. 40 to 60 %. Therefore, this zone is not also fully safe and the entire zone can be explained as warning zone for human habitation unless sufficient cautions are taken care of. This zone covers 1337.3 km^2 area of the Darjeeling Hills.

Low Zone of landslide hazard

This zone covers three distinct areas of the Darjeeling hills, one situated on the northwest corner in Darjeeling Sadar subdivision, another in the southern most end of the Kurseong subdivision and the 3rd one on the southern part of the Kalimpong subdivision. This zone suffers from little to no chance of landslide as occurrence frequency of landslide is ≤ 20 % and therefore, can be explained as safe for human habitation from the view point of landslide hazard. But this zone covers a very little area i.e.225.08 km^2 of the Darjeeling hills.

CONCLUSION

From the above discussion, it is clear that preparation of hazard zonation map helps to identify various degrees of hazards associated with different zones over a region and gives a compact and complete view of the different zones with varied degree of safety level. This can help planners and decision makers to undertake management strategies over different zones on priority basis and capacity building plans to mitigate the hazard risk.

The landslide hazard zonation map of the Darjeeling hills clearly reveals that a well management strategy is essential to reduce and restrain the severity of landslide hazard in the hills of Darjeeling since most of the area falls within the grip of landslide risk. Therefore, this is the high time to take necessary steps than to get confined within the discussion of the bleak view of the landslide hazards occurring over this region.

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