

## Causes of Landslides in Darjeeling Himalayas during June-July, 2015

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### Introduction

Landslides are the significant form of natural disaster that causes the loss of properties and lives, especially in the mountainous areas. The mountainous terrains are characterised by high energy with instability and variability of the masses [1]. Landslide differs from the other mass movement processes and it is the movement of the mass occurs primarily along a discrete failure surface. The internally unreformed plane slips the materials and disintegrates the mass and further movement includes the flow element [2]. In India, most of the hilly regions are characterised with the landslide disaster. In the Himalayan region, several avalanche zones are prominent, such as Jammu Kashmir, Himachal Pradesh, Kumayun, Darjeeling and Sikkim and North-eastern hilly states [3]. In the Himalayan foothills where rainfall is prominent, the occurrence of landslides is significant. The Darjeeling and Sikkim Himalaya are among the most vulnerable areas of landslides. The main triggering factors (excluding geological and geomorphological) of the landslide are heavy rainfall and seismicity [4]. Of late, landslide disasters have been accelerated by the several anthropogenic activities in this region [1]. However, to mitigate or reduce the occurrences of landslide, landslide susceptibility [5] mapping of landslide hazard [6,7] along with engineering geomorphology [8] are some of the post landslide initiatives.

Recently, in Darjeeling Himalaya, major landslides have occurred in July-August, 1993 and May 2009 and in September 2011 [9]. Heavy rain has triggered landslides at Mirik, Darjeeling, Kalimpong and Kurseong during June-July, 2015, causes the loss of several lives and properties. Several factors may be responsible for the landslip. Hence, the main causing factors of the landslide have been discussed based on some historical analysis without any statistical or physically based model. This is in the format of an informative report; therefore, no analyses or assessment was conducted to measure the effect and spatial characteristics of the landslides in the study area.

The Darjeeling Himalaya is a part of Lesser Himalaya. The elevation of the region ranges from 500 m to 2500 m above MSL as Figure 1. Due to varied geomorphology and neotectonic activities, the region is one of the highly earthquake-prone areas. The main rock types of the Darjeeling Himalayas are Pre-Cambrian high-grade gneiss and quartzite, high-grade schist phyletic and calc-silicate and quartzite [10,11]. The major soils of this region are characterised by high concentration of iron oxide with the lack of mineral and organic nutrients. The sedimentary rock of young folded mountain promotes the active erosion in Darjeeling Himalaya. This region is highly vulnerable to landslides and the onset of monsoon in the north India usually culminates into massive high rainfall over the Himalayan foothill belt [12].

### Occurrences of Landslides - Why?

The primary causes of the landslides are the varied and intensive rainfall [13] and earthquake [14]. Landslides are often the subsequent event of intense rainfall. Rainfall lubricates the materials slip off from the parent body and moves downward under the force of gravity. During the downward movement of earth unconsolidated materials, the force of gravity exceeds the resistance to shearing. The percolation of water through the soil pore space accelerates the probability of occurrence

of the landslides. Landslides are also caused by the earthquake shock. The tremor generated by the earthquake can disturb the underlying structures of the hilly region. The shock can disrupt the underlying parent body and as a result landslide along with the fall, slump, and the slide occurs.

The anthropogenic activities such as the unscientific uses of the slope for construction, deforestation and the development of towns and tourism industry are also responsible for the increase of the vulnerability of landslide in this region [15]. Sah and Bartarya [16] have given some causes for the occurrence of landslides in The Himalayan region. The causes are the dynamic forces (earthquakes, neotectonic activity etc.), an increase of pore space due to high rainfall, the increment in internal pressure due to chemical and physical alteration, and unscientific land use, mining and quarrying etc.

### History of Landslides in Darjeeling Himalayas

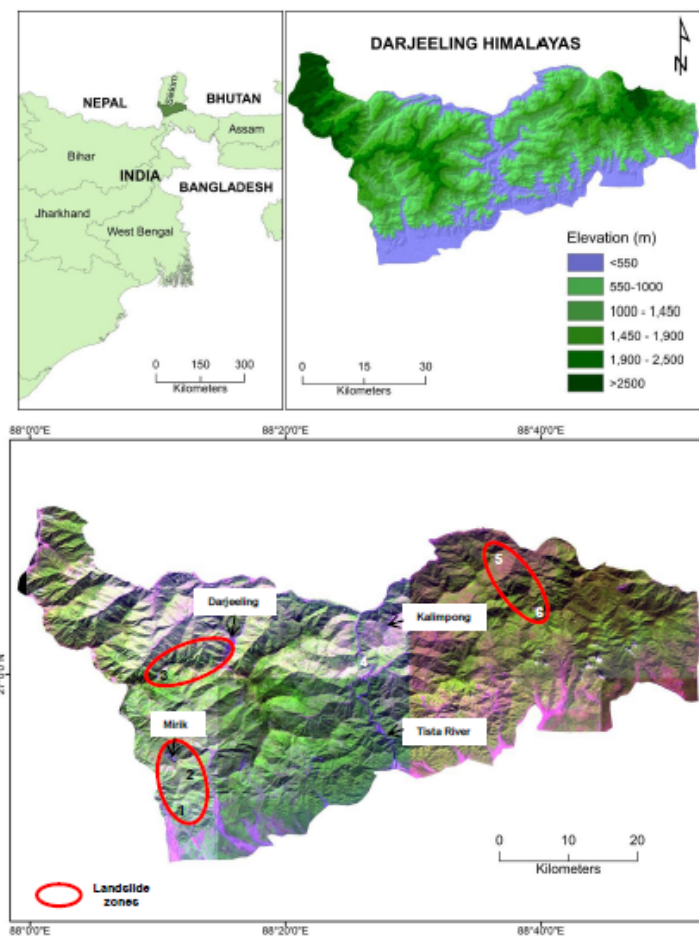
Darjeeling Himalayas belongs to the Eastern Himalayas ranges. This region is drained by many streams and rivers such as Tista, Rangeet, Mahannda, Jaldhaka, Balason, Mechi, Lish, Gish, Murti etc. The major towns of this region are Darjeeling, Kalimpong, Kurseong and Mirik. This region is composed of soft phyllite, schists, and gneiss and this region are high susceptible to a landslide. The occurrences of landslides are prominent from a long time of history. As per the landslides records available, the disastrous landslide was occurred in September 1899, in which 72 lives were lost in Darjeeling town. Kalimpong, Kurseong, Ghum, Tindharia of the Darjeeling Himalaya were also affected by this disaster. In January of 1934, the occurrence of the landslides is significant in Darjeeling, Ghum and Kurseong town. Massive landslides were occurred in June 1950, in which 127 lives were lost along with the loss of several properties including roads and Siliguri-Kalimpong railways line. The affected areas were Darjeeling town, Kalimpong, Kurseong, Happy Valley, Tindharia, Takdah. In another occurrence of landslides, 667 lives were lost along with the destruction of a tea garden and it occurred on October 1968. The affected areas of the landslide were Darjeeling town, Manpuri, Lebong, Kalimpong, Tista Bazar, etc. The Hill Cart Road and NH 31 of Darjeeling were severely destroyed. Again, Rimbik, Lodhama, Darjeeling Town, Bijanbari, Lebong, Ghum, Happy Valley were affected by the landslides that occurred on September 1980. In the slides about 215 people were lost along with the several properties. However, several landslide disasters happened in the year of 1991, 1993, 2003, 2004, 2005, and 2006 [17,18]. All of the slides occurred in the Darjeeling Town, Kalimpong, Kurseong, Pulbazar,

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Received April 20, 2016; Accepted May 26, 2016; Published May 27, 2016

Citation: Sumantra SB, Raghunath P(2016) Causes of Landslides in Darjeeling Himalayas during June-July, 2015. J Geogr Nat Disast 6: 173. doi:10.4172/2167-0587.1000173

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**Figure 1:** Location map of Darjeeling Himalayas and the major sites of occurrence of landslides are represented by red circle. These sites are 1: Tingling, 2: Soureni, 3: Sukhia Pokhari, 4: 29 miles, 5: Pedong, 6: Lava.

Rongtong, Tindharia, etc. 15 people were killed at Mongpoo and several properties were lost in the slide of July 1993. In August 2009, three people were lost in a landslide that was occurred on Nimbong, Kalimpong, Kurseong, and Mirik after a heavy rainfall of 190 mm. The surrounding of the Kalimpong town suffered more damage than that were at Darjeeling during the Cyclone Aila. The landslide of June 2011 was the subsequent effects of high rainfall of about 152 mm at Darjeeling and 60 mm rainfall in about 3 hours at Kalimpong, Kurseong. In this landslide, no such significant casualties had occurred. In the same year, in September, the landslides occur due the subsequent effect of Sikkim earthquake but the Darjeeling Himalayas has been less affected than the Sikkim Himalayas [19].

In the Darjeeling Himalaya, most of the landslides are the result of subsequent rainfall effects (except the landslide of 1934 and 2011 (September) that occurred due to earthquake).

### Landslides during June-July, 2015

The landslides in the Darjeeling Himalayas are common. Heavy rainfall triggered the landslides at numerous places of Darjeeling Himalayas in June-July of 2015. The landslides occurred mainly in Darjeeling, Kurseong and Kalimpong sub-division of Darjeeling district during June-July, 2015. The main affected areas are Tingling and Soureni of Mirik, Nimki Dara, Sukhia Pokhari of Darjeeling, Lava,

11 miles (name of a place of Darjeeling District), 29 miles (name of a place of Darjeeling District), Pedong of Kalimpong. The total death toll reached up to 38 and several people were misplaced. Several properties were lost, and roads were disconnected. The NH 55 that connect Siliguri and Darjeeling were disconnected as a bridge washed away at Nimbujhora. The NH 10 were also disconnected the communication between Kalimpong and Lava. Many domestic and international tourists were affected for the disconnection of the communications. The landslides have disrupted the track of historical 'toy train' of Darjeeling Himalayan Railway and the Darjeeling Himalayas was disconnected in the rail network over a month. Thus, due to the disconnection of transportation and communication, the normal life of the northern Darjeeling and Sikkim is disrupted. The scarcity of the fuel gas and petrol and diesel has increased in this region. A massive amount of debris is scattered throughout the region. It took time of over a month to clean the debris and re-establishment of the regular communication. The traffic congestion is a real picture as the most of the vehicle could not go through the highways (Figure 2).

The region having steep slope is associated with rock fall and debris fall and is affected much than the gentle slope. On the contrary, in the valley side area, debris materials such as talus and scree deposits block the roads and disconnect the communication. The scree deposits also accumulate on the Tista, Rangeet, Mahananda, Jaldhaka, Balason



**Figure 2:** Landslides on different road stretches and on inhabited areas (Mirik) in Darjeeling Himalayas. **Sources:** Anandabazar Patrika and Bartaman (Bengali newspaper).

River, etc. This accumulation may further lead to flash flood with a heavy downpour in the upstream regime of the rivers. Many experts have identified several causes for the landslips. Several factors can be responsible for the recent landslides. The main factors for the landslide are such as:

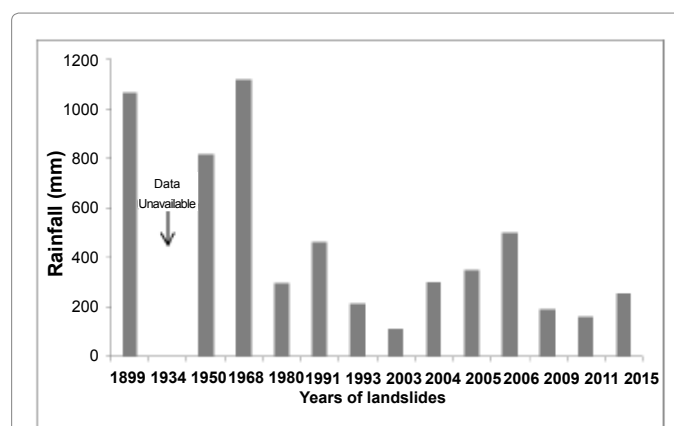
### Heavy rainfall

The heavy rainfall triggered the landslides through the percolation in the joints and cracks. The rain acts as a lubricant matter that induces the occurrence of landslides. The rainwater percolates through the soil pore space and the cracks and joints of the rocks. The materials also become saturated and these increase the effective weight of the materials. This mechanism reduces the resistance and stability of the parent rocks. In the Darjeeling Himalayas, before the occurrences of the landslide, the average rainfall was above 200 mm. The average precipitation in June to July of Darjeeling is 600-800 mm. But, at the preceding time of landslide, Kalimpong have faced a torrential downpour of 254.4 mm in just 24 hours. Thus, with the addition of heavy rainfall, the lubricated unconsolidated matter slips down as the subsequent effect of heavy torrential rainfall. This induces the occurrences of landslides at Mirik, Kalimpong, Kurseong and Darjeeling. Figure 3 signifies the massive heavy rainfall has caused several landslides in this region. Most of the landslides are the subsequent effect of heavy rainfall.

### Geology with neotectonic activity

The whole region is composed of soft Phyllite, Schists, and Archean gneiss and having a deep between 20 to 60 degrees [20]. The soft sedimentary rocks are more vulnerable to erosion. The region consists of several cracks, joints that increase the probability of decomposing and disintegrating the rock to form unconsolidated matter. The cracks and joints also accelerate the permeability of parent body and the water during heavy downpour can easily penetrate, and the parent body becomes lubricant. Thereby, this composition increases the probability of occurrences of the Darjeeling landslide disaster.

In this region, the soils are mountain soil that is characterised by the high organic matter, high water holding capacity and volume expansion. Due to the continuous percolation towards the bottom layer, the middle portion of the soil horizon is associated with the coarse textures. That reduced the shearing strength of the soil and enhanced



**Figure 3:** Simultaneous occurrences of landslide and heavy rainfall that indicates the occurrences of landslide due to heavy rainfall.

the materials to move downward along the slope of the roadsides and valleys in the Darjeeling Himalayas.

### Presence of Mirik Lake

The Mirik Lake is also taken into consideration as a landslide-inducing factor for the recent occurrences of the landslides in this region. Due to the presence of the lake, there is continuous percolation of water through the soil pore space and the joints and cracks of the parent rocks and this percolation rate is enhanced with the onset of the Monsoon. The parent rocks having the joint and cracks of surrounding areas of the Mirik Lake, become lubricant with the heavy downpour and thus there is a reduction in the resistance than the stress. Vis-à-vis, liquefaction, is also significant in the surrounding area of the lake and this can promote to lubricate the materials. As a consequence, the occurrence of landslides is significant in the Mirik and its surrounding areas (Tingling, Soureni). This is also a reason for Mirik to turn into the most affected region of June-July landslide (2015) disaster than the Kalimpong and Kurseong.

### Anthropogenic activities

The anthropogenic activities are one of the major factors for the recent landslides in the Darjeeling Himalayas. The anthropogenic

activities include the continued cutting of the vegetation due to the construction of the multi-storeyed buildings, roads for communication and tea cultivation. In Mirik, the cutting of the vegetation is significant for the tea cultivation. The removal of vegetation reduces the cohesiveness of the soils and the parent body. Thus, it has enhanced the vulnerability of landslides with the addition of heavy rainfall in the surroundings of Mirik. The continuous construction of the buildings and roads have accelerated the vulnerability of the landslide at Mirik, Kalimpong, Kurseong and Darjeeling. Cutting off the natural slope in an unscientific manner reduces the shearing strength of the parent body and increase the vulnerability of landslides. The number of roads is growing in Mirik. The settlements at Darjeeling, Kalimpong and Kurseong town have been increased and continuous increase of multi-storeyed buildings in an unscientific manner disturbs the natural slope of the region and thus reduces the shearing strength of the parent body. Thus, the slope bears an enormous amount of weight in the reduced shear strength parent body. With the increase of the urbanisation and tourism industry in Darjeeling Himalayas, the use of non-biodegradable matter is increased that further prevent the movement of the natural percolation of water through the soil pore space and parent body. Thereby, the cohesiveness of the parent materials is disrupted that result the occurrences of a landslide during June-July (Figure 4).

Several factors are responsible for the landslides in the Darjeeling Himalayas. Few of them are responsible for the June-July 2015 landslide. However, some experts have demonstrated that the structure and lithology of Darjeeling Himalaya were disturbed by the occurrences of earthquake shock in the Nepal Himalayas (April 25, 2015). The subduction of the Indian Plate beneath the Eurasian plate generates an enormous amount of energy that shocks the underlying structure of the Darjeeling and Sikkim Himalayas. As a result, several cracks and joint formed and loosed the parent rock structure in the entire Darjeeling as well as Sikkim Himalayas. But this is not the primary reason for the landslides as the landslides are concentrated in some pockets in Darjeeling Himalayas. There is no example of such type of occurrences of a landslide in the Sikkim Himalayas. If the Nepal earthquake is solely responsible for the landslide, then the whole eastern Himalayas would face the landslide disaster throughout the year whenever earthquake occurred and not during the monsoon season only. So, it can be summarised from the history of landslides of Darjeeling Himalayas that the prime reason of the landslides is intense rainfall. Thus, the landslide of June-July (2015) is mainly caused by the heavy torrential rainfall with high rainfall intensity. The construction of highways is also the major responsible factor as the civil engineers have no comprehended about the natural slope at the time of cutting the slope for highway construction.

The toe erosion of the rivers also induces the occurrence of the landslides in the valley area [21,22]. It also can be taken into consideration that the role of Mirik Lake is significant for the landslide disaster at Mirik.

## Conclusion

The Darjeeling Himalaya region is the most vulnerable to a landslide as well as avalanche, fall, slump disaster. The primary effects of the June-July landslide disaster are the disconnection of the roads, loss of lives, the breaking of bridges, etc. The people have lost their home and suffered homelessly and took shelters that are provided by state government. Thus, the landslide disaster of 2015 triggers severely the natural environment of the Darjeeling Himalayas. It is caused by the natural phenomena viz. heavy torrential rainfall but the intensity and magnitude are enhanced by the anthropogenic activities. A recent geological survey conducted for the Darjeeling Landslide by the Survey of India and the report says that the Nepal earthquake has a significant role in the occurrence of the Darjeeling landslide. However, on the basis of historical record it can be said that intense rainfall is the key factor for the June-July, 2015 landslide. As the developmental activity is increased in the mountainous region, thereby, the land use management is significant to reduce the vulnerability of the landslides.

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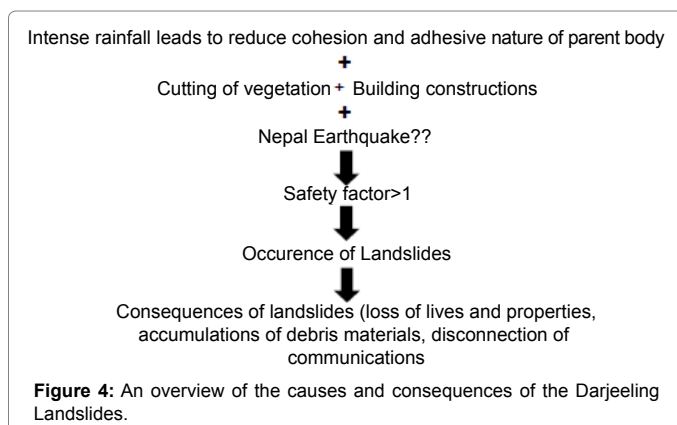


Figure 4: An overview of the causes and consequences of the Darjeeling Landslides.

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**Citation:** Sumantra SB, Raghunath P (2016) Causes of Landslides in Darjeeling Himalayas during June-July, 2015. *J Geogr Nat Disast* 6: 173. doi:[10.4172/2167-0587.1000173](https://doi.org/10.4172/2167-0587.1000173)

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