Effect of drawdown of Karli Lake: A Case Study of Karli landslide hazard in District Hattian, Northeast Himalayas of Pakistan

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Abstract: In the northern part of Pakistan, thousands of landslides were triggered during the 2005 Kashmir earthquake. On 24 March 2014, the Karli landslide, located in district Hattian, about 65 km southeast of capital city of Muzaffarabad, Pakistan was reactivated due to heavy rain fall. Simultaneously, another slide adjacent to the main slide was triggered that transformed rapidly into earth flow. In order to investigate the Karli landslides, field investigations were carried out two weeks after the reactivation of Karli landslide. In addition, SPOT and Google imageries were used to delineate the affected area. DEM was used to study the topographic characteristics of the area. The landslide affected area measuring about 1000 m long and 800 m wide damaged about 156 houses and displaced 900 inhabitants. In addition, on 24 March 2014 earth flow destroyed 3 houses completely and many others are under potential threats. On the basis of field observation and satellite data it is inferred that the Karli landslide was outcome of breach out of Karli lake in February 2010. The landslide movement initiated after falling down of water level of the Karli lake. The landslide hazard assessment indicates that the affected area is under continuous threat of landslide due to the effects of drawdown of Karli lake. Therefore, the inhabitants of the Karali area are under potential risk and need to be relocated to the safer places.
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Key words: Karli landslide; Muzaffarabad; Himalaya; Hazard assessment

1 Introduction

The Karli village, covering an area of about 6 km^2 is located in Hattian District (near Chikar town), about 65 km southeast of capital city of Muzaffarabad, Azad Jammu and Kashmir, Pakistan (Figure 1). Total population of Karli village is about 2,400 (Land Use Planning, 2012). The Karli area has experienced several landslides during and after the 2005 Kashmir earthquake (Dunning et al, 2007; Owen et al, 2008; Basharat et al, 2012). These landslides resulted, combination of various factors including natural and human related activities. Moreover, the geological, geomorphological, and hydrogeological environment of the area are major contributing factors causing landslide activity in this area (Harp and Crone, 2006; Scheinder, 2008; Basharat et al, 2014).

The 2005 Kashmir earthquake triggered thousand of landslides in northern part of Pakistan and Kashmir (Sato et al, 2007; Owen et al, 2008; Kamp et al, 2008; Basharat et al, 2014). Among these landslides, the Hattian Bala rock avalanche was the biggest one having volume more than 100 million m^3 (Basharat et al, 2012). This huge landslide blocked the flow of Karli river and Tung tributaries creating two landslide dams. The Karli dam covering the surface area of 1.2 km^2 had the water storage capacity of about 62 million m^3 (Sattar et al, 2011; Kiyota et al, 2011; Figure 1). In February 2010, 5-days continuous rain resulted in a breech out of the Karli lake. The outcome of the flood waves caused heavy destruction along the way down stream to Hattian leaving one person dead, and many houses completely or partially damaged (Basharat et al, 2012). Furthermore a number of landslides were activated up- and down-stream in the Karli valley (Sattar et al, 2012). Among these activated landslides, the Karli landslide was outcome of breach out of Karli lake on 9 February 2010, covering an area of about 1 km^2. This devastating landslide affected the local inhabitants and the environment of the area.

On 24 March 2014, in Karli area, due to heavy rain fall the material of Karli landslide was remobilized at the upper slope and transported through surface channel. Simultaneously, another slide adjacent to the main slide, known as earth flow, was triggered by heavy rain fall. This earth flow destroyed 3 houses and rendered many others under potential risk. The aim of this investigation was to understand the cause and effect of Karli landslide. For this purpose field investigations were conducted in April 2014. In addition, SPOT and Google imageries were used to map the affected area of Karli landslide.

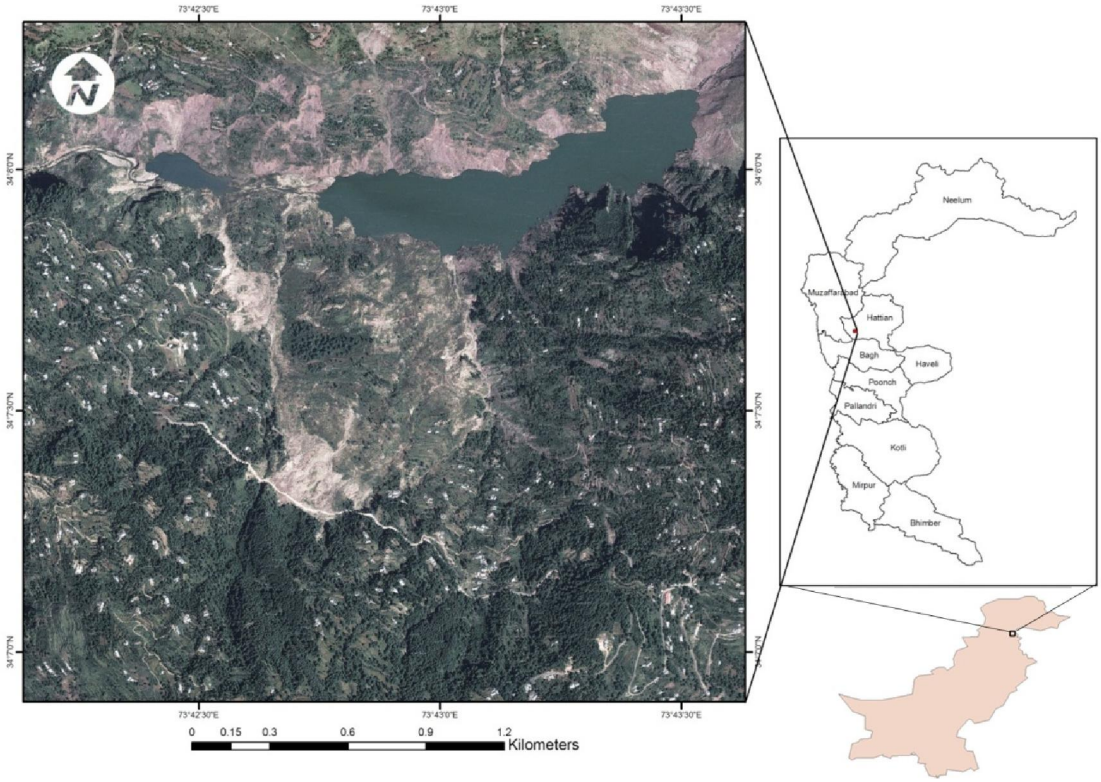

Figure 1. The Google earth image showing the location of the Karali landslide and surrounding area.

2 Geographical and Geological Setting

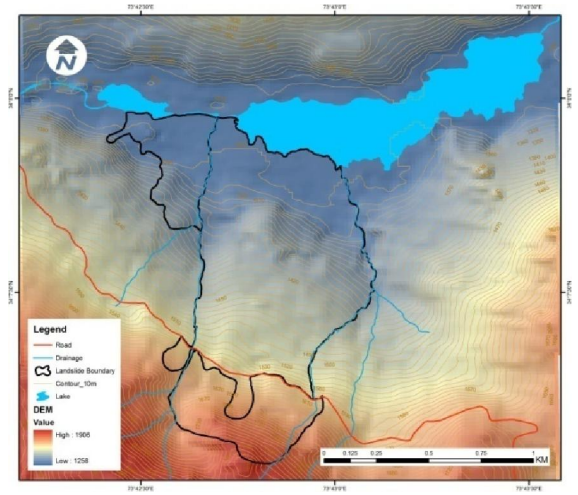

Figure 2. Hillshade map shows the topographic features of the Karli area.

The Karli area has characterized moderate to steep slopes and uneven topography (Figure 2). The high local relief, steep slopes, and a structurally controlled hydrographic network are the most typical geomorphic features of the area (Figure 3). The other geomorphic features are associated with fluvial and slope processes. Many old landslides and erosional processes have modified the escarpments. The well known faults of the area named the Muzaffarabad Fault running toward NE–SW direction passes within the affected area (Hussain et al, 2004; Baig 2006; Kaneda et al 2007). Weathered and loose unconsolidated materials have been eroded, transported, and deposited at low elevation areas. The loose materials transported through the valleys have been deposited as alluvial and colluvial fans.

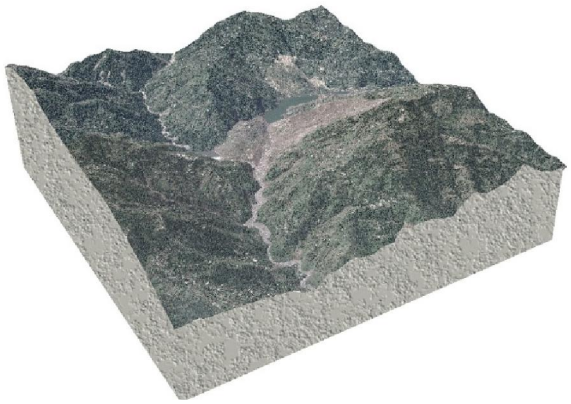

Figure 3. 3D view of the area shows the topographic features.

The detailed geological features of the Karli area have been studied from the Geological Survey of Pakistan (GSP) and are presented in a geological map (Wadia, 1931; Calkin et al, 1975; GSP, 2008; Figure 4). In the study area, the Muzaffarabad Fault runs entirely within the Murree Formation and the Kamlial Formation or the Quaternary sediments . In general, the area is composed of Miocene to Quaternary strata. The Miocene layers trend SE-NW with several small anticlines and synclines. The Miocene Murree and Kamlial formations are mainly composed of interbedded sandstones, siltstones, shales and mudstones (Shah, 1970; Calkin et al, 1975). The Quaternary layers consist of alluvial talus and terrace deposits. The rock sequence shown in Figure 4 includes the early Miocene of Murree Formation, the late Miocene of Kamlial Formation and Quaternary sediments.

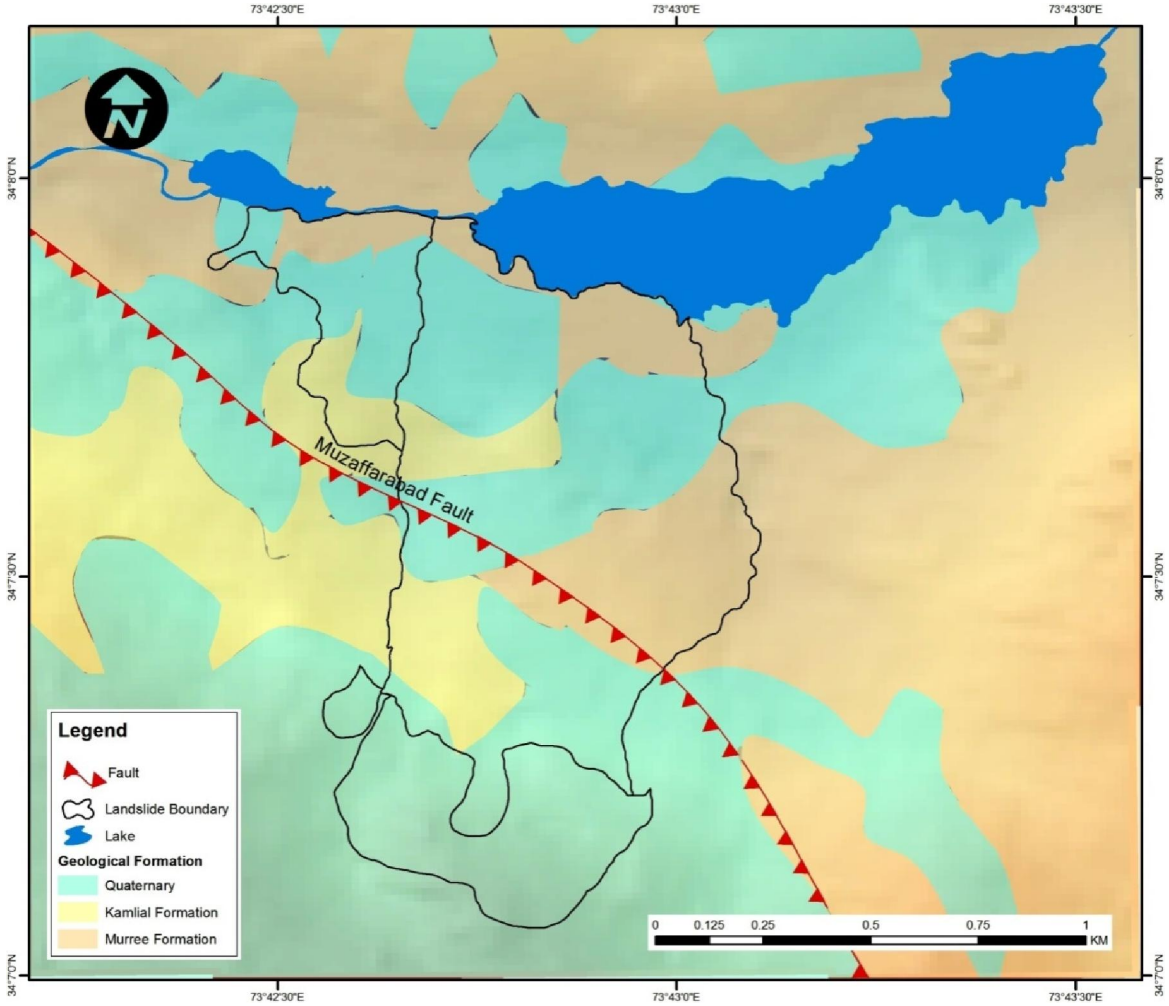

Figure 4 Geological map of Karli area compiled and modified after Geological survey of Pakistan (2008).

3 Material and Method

The present study based on field investigations with incorporated satellite data and DEM. Intensive ground based field investigations were carried out in April 2014 on base map of 1:10,000 scale. SPOT and Google imageries were used to identify the location of the landslide. During the field investigation, area of landslide was delineated and main scarp was identified. A significant component of this field visit was to assess the potential threat of landslide in future. The main scarp of landslide was mapped using GPS waypoints and plotted on the contour and hillshade maps. The landslide dimension and travel path were measured by using ordinary measuring tape. ArcGIS 9.3 software was used to map the landslides for this study. A geological map prepared by GSP (2008) was used to characterize the lithological units of the area.

4 Description of Karli Landslide

According to local inhabitants the Karli landslide was first time triggered in 1973 at the right bank of Karli. In 1992 flood triggered the Karli slide at the

upper part of the slope and damaged the Sudhan Gali – Bagh road (Figure 2). The 2005 Kashmir earthquake triggered the Hattia Bala landslide that blocked the Karli and Tung river and formed landslide dams. In February 2010, following the 5 days heavy rain fall, Karli dam breached out that resulted activation of Karli landslide. According to the local eyewitnesses the landslide movement initiated after falling down of water level of the Karli lake (Figure 5). The movement of the area continued for about a weak. The affected area measuring about 1 km long and 800 m wide (Figures 6) damaged about 156 houses and displaced 900 inhabitants. At present the total area of Karli landslide is 195 acers and 45 acers area poses a potential threat of landslide in future.

Figure 5. In February 2010, Karli lake breach out that resulted activation of landslide

Figure 6. The recent earth flow destroyed three houses at the toe of Karli slide and houses at the scarp are under potential risk.

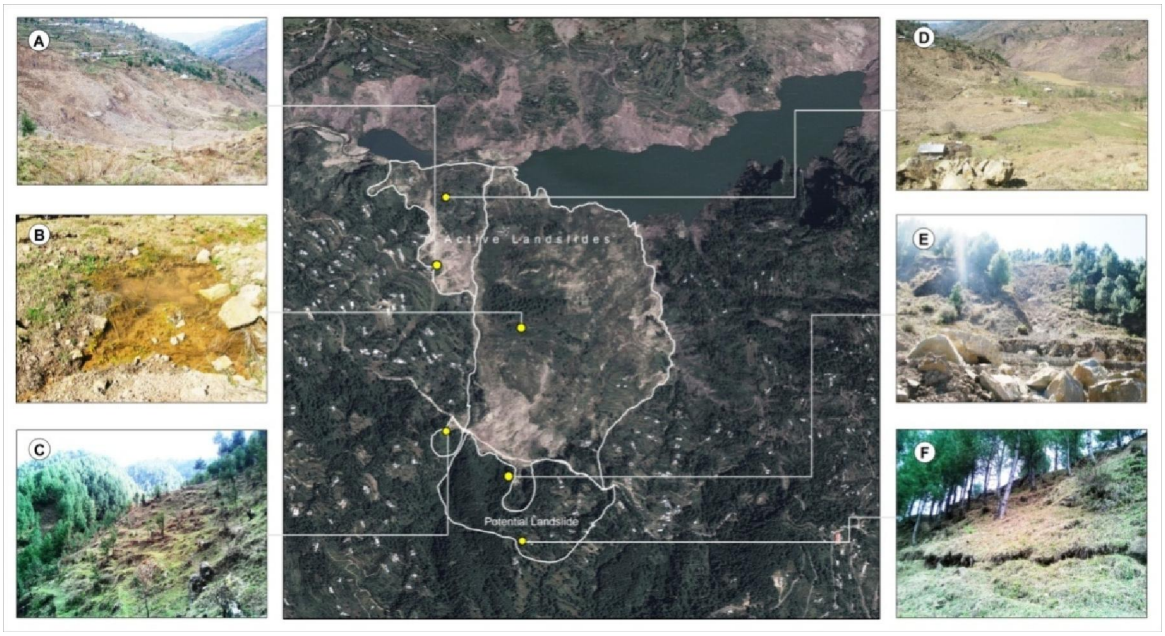

Figure 7. Features of the Karali landslide source and deposit area; a) The houses present at the scarp are under potential threat; b) Presence of pond indicate the potential hazard of flow; c) Deforestation contributed the failure of the main scarp d) Landslide damages to the houses e) View of the landslide main scarp; f) The rupture at the main scarp indicate the potential landslide hazard in future.

Filed observation indicate that a sudden breached out of Karli lake would have disturbed the equilibrium conditions. Pore water pressure gradient in the slope would have increased that led to the increase in seepage forces to the threshold that triggered the heavy landslide (Figure 7a). This hypothesis is supported by the evidences such as presence of seepages and pond in the affected area (Figure 7b). On 24 March 2014, following the heavy rain fall another slide was triggered in the Karli area that moved downward and

transformed rapidly into earthflow (Figures 7c and 7d).The seepages, surface run off and springs played an important role in transforming the clayey material into flow. The subsequent surface runoff and seepages increased the ground water level and saturated the base of the slope that contributed earth flow. The recent earth flow destroyed 3 houses completely and many others at the scarp of slide are under potential threats (Figure 8). Two types of landslide hazards were evaluated: deep seated translational slide that occurred in February 2010 and recent earth flow of 2014. Besides aforementioned factors the other factors like the deforestation, surface runoff, shallow ground water, weak underlying material and proximity to the Muzaffarabad Fault also contributed to the Karli landslides.

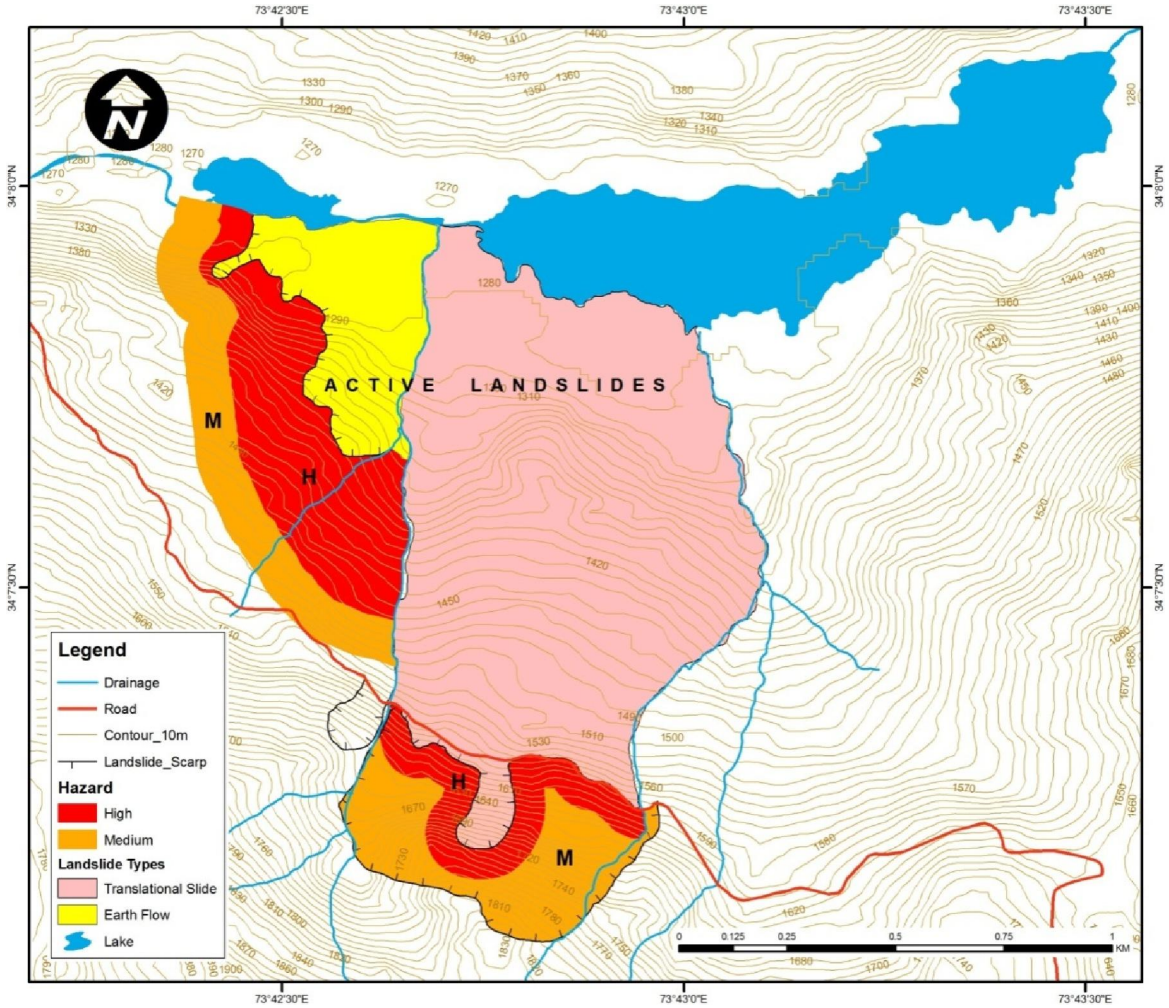

Figure 8 Map shows the Karli landslide source and deposit area. The Polygons show the boundaries of landslide and buffer indicate the future potential hazard zone of the area.

5 Future Landslide Hazard Potential

The February 2010 and March 2014 Karli landslide clearly demonstrate the potential for deep transitional and rapidly moving earthflow type landslide with significant displacement of the area (Figure 9). Flow type landslides are destructive and threat to life safety due to their velocity and impact. When such type of landslide occurs, the potential threats are loss of life and property damage. In Karli area, both landslides have potential to damage the houses and are future life risk. The affected area being under continuous threat of significant displacement is not recommended for any type of construction. It is therefore timely to relocate the inhabitants of the area to the safer place as soon as possible.

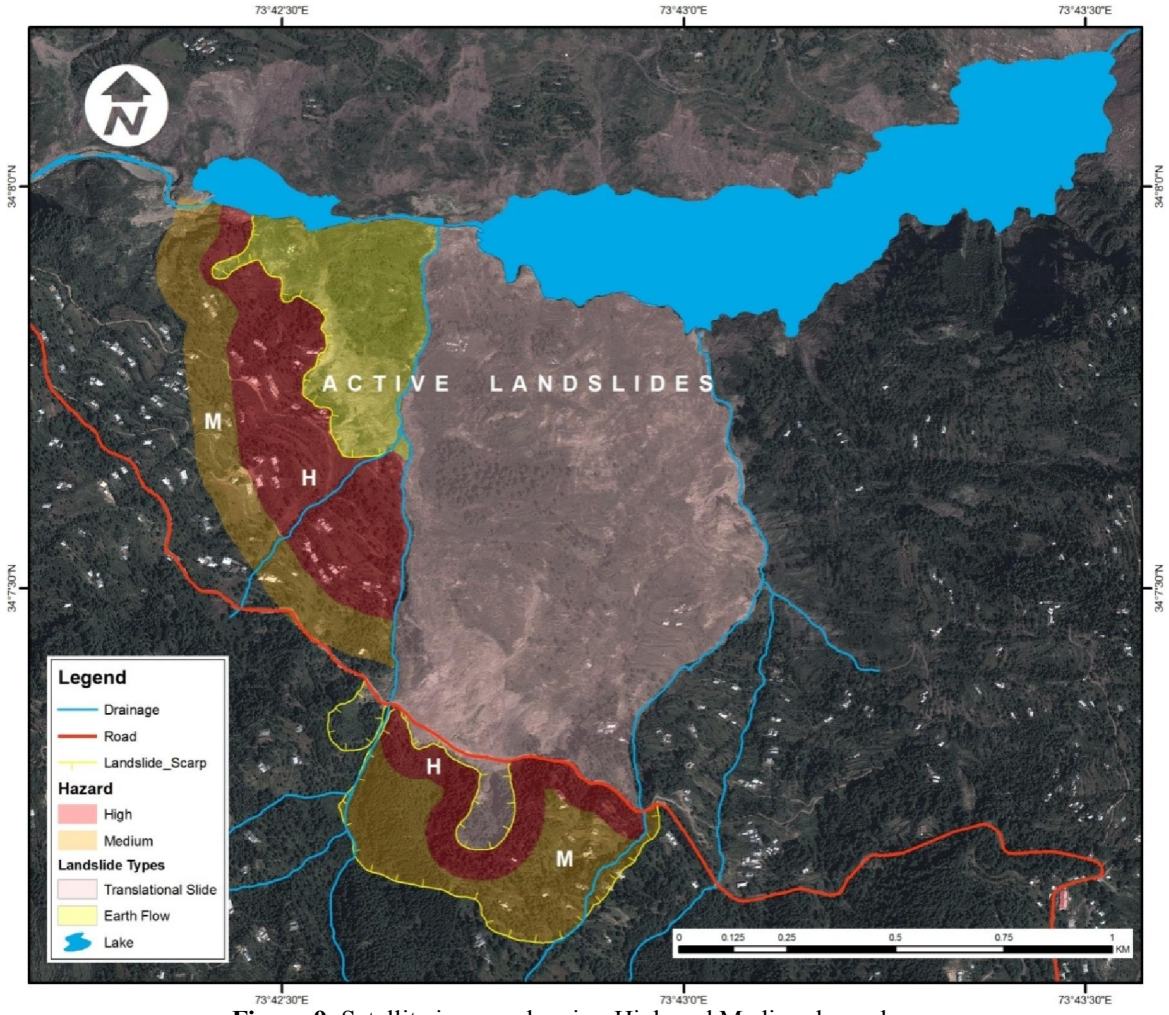

Figure 9. Satellite images showing High and Medium hazard area

6 Conclusions

Based on the investigation regarding landslide hazard assessment of Karli area, the following conclusions are drawn.

1. Terrain mapping and landslide hazard assessment indicate that Karli area is under the continuous threat of landslide in future.
2. Heavy rainfall and drawdown of Karli lake that disturbed the equilibrium conditions of the area leading to increase pore pressure that activated the Karli landslide in 2010.
3. The surface run off, seepages, shallow ground water and clayey material probably contributed to the 24 March 2014 earth flow that destroyed three houses.
4. Houses already existing in the Karli landslide area and on the left flank of the landslide scarp are under potential risk.
5. The hazard of the area has been classified into High and Medium zones.
6. In future, heavy rain fall may cause similar risk of significant displacement of the area marked as High and Medium zones.

Acknowledgments

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