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Assessment of Landslide: A five decade impact study on human life in the Koshi Province

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Abstract

Koshi province covers about 82 % of hills and mountain region. Rugged and fragile geomorphology is our landform's characteristics with various reasons like rock structure, slope, rainfall and unplanned settlement as well as developmental intervention. Geological, morphological, human and physical causes are common factors to trigger the vulnerability. This study has found that 990 human lives have lost and around 107,259 people have affected during 1971- 2020 in the Koshi province of Nepal. Likewise, the maximum number of deaths was 114 people in 2002 and the minimum deaths was 1 person in 1987 during same period. Out of 14 district, four districts have been identified very extremely vulnerable which include Taplejung, Khotang, Okhaldhunga and Sangkhuwasabha, while other four districts Bhojpur, Solukhumbu, Ilam and Panchther are extremely vulnerable districts in terms of landslide hazard. In addition, the analysis of number of human deaths caused by landslide shows that the impact of human life and properties has been fluctuating in each decade over the fifty years. There was high vulnerability of human life in the decades of 1990s and 2000s. In order to reduce the landslide risk in the surroundings of mountain people and their environment, preparedness of adaptation measures should be considered in the future.

Key words: *Landslide, causes, human and impact.*

Introduction

Landslide is a serious risk in the mountains and hilly areas. It has become the severe threat for the lives of local peoples and their livelihoods. It can take long time to recover such effects in the society (Sahoo, 2009). Landslide is natural hazard that moves toward downslope with the mass of regolith or bedrock (Saxena, 1999). Rock, soil and organic materials includes the downslope movement as a landslide which depends on effects of gravity. Landform also determines the results of materials movement on the earth surface (Hilland & Bobruwsky, 2008). Landslide is observed especially in mountain terrain. It occurs as a natural hazard in the steep slope. In the latest period, the occurrence of landslide can be observed along the road alignments in the hilly areas which has been creating more vulnerable zone. The frequency of this event triggers from heavy rainfall. We have a lack of technology that can precisely predict how much of landslide would occur in a particular landscape.

Landslide is the natural phenomenon in the land of high altitude that flows unexpectedly downward the decomposing of rocks materials in the earth surface. The materials can transfer by falling, toppling, sliding, spreading and flowing with the help of gravity force (Raya, 2011). It is also geological incidence which includes the rock falls, debris flows and deep failure of slopes. Other contributing factors may result in the slope instability. The occurrence of landslide depends on various factors which are acting either together or alone. Earthquake, volcanic eruptions,

torrential precipitation, soil structure are some examples of natural factors. On the other side, deforestation, cultivation, construction, vibration or blasting and big developmental works are anthropogenic factors. As a result, it encompasses the wide range of mass movement of rocks and soil, erosion of top soil, destruction of roads or bridges or reservoirs, loss of human lives and properties in the mountain side. It has also been affecting the lower part of landscapes, i.e., deposition and siltation in the lower valley as well as plain areas.

Nepal has been frequently facing various natural disasters. Avalanche, landslide, drought, earthquake, floods, Snow storm, thunderstorm, heat and cold wave etc. are main disasters in Nepal. Of 14 total natural disasters, landslide is prominent in Nepal because of Siwalik, Hills and Mountain relief feature and boundary of tectonic plate between Eurasian plate and Indian plate. Torrential rainfall also carries the landslide events which occur everywhere in the sloppy areas mostly during the rainy seasons generating various toll hazardous environments all over the country. For instance more than 2000 landslides had occurred along the Tribhuvan Highway alone due to the rainstorm in 1993 (Dhital, et al., 1993).

Methods and Materials

This article tries to assess the landslide hazard in Koshi province, Nepal over the fifty year period. The study is based on secondary information. The information was collected from DesInventar (as a Disaster Information Management System) Database managed by United Nations Office for Disaster Risk Reduction (UNDRR) between 1971 and 2013. It has also added other time series data from Nepal Disaster Risk Reduction Portal (DRR Portal), Government of Nepal between 2014 and 2020. Both the data have been added for generating five decade information. Based on these data, the district-wise landslide hazard mapping are distinctly prepared. Spatial distribution of landslide is assessed by using geographic and attributes data of five decades. Geographic Information System (GIS) tool is applied for deriving landslide prone areas in Koshi province.

Koshi province composed of altogether 14 administrative districts of Nepal where nearly 81.69% area is covered by hills and mountain (Pokharel, 2021). Of total 14 districts, 11 districts are located in mountain and hilly region of Koshi province of Nepal. Remaining 3 districts are located in terai region. Landslide is a major natural disaster in Nepal. Rugged topography and cloudburst are the main reasons for landslide in mountainous areas. Landslide has been massively affecting the human settlements and their properties every year. This hazard are huge damaged of properties including agricultural land during rainy season.

Types of Movement

Landslides are of different types in term of its involved materials and the mode of movement. The types of movement are divided into six groups: falls, topples, slides, lateral spreads, flows and complex movement. Slides can be further subdivided into two groups: rotational slide and translational slide. Rock and soil are the two materials mainly involved in the slides. Based on size of soil particle it can be additionally subdivided into debris and earth materials during slide movement (Varnes, 1978). The various types of landslide can be differentiated by the kinds of material involved and mode of movement.

Table 1: Types of Movement

Types of Movement		Type of Material		
			Soils	
		Rock	Predominantly coarse	Predominantly fine
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
Lateral Spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow (deep creep)	Debris flow (soil creep)	Earth flow (soil creep)
Complex		Combination of two or more principle types of movement		

Source: Varnes, 1978

Causes of Landslide

The causes of landslides vary in each places. Landslide occurrence depends on terrain and geo-environmental factors (Margottini, et al., 2011). For examples, nature of land topography, geological structure, slope morphology, weathering, water flow and land cover are the main factors for triggering landslide. Cruden & Varnes (1996) stated that it can be broadly divided into four common casual factors: i) geological cause, ii) morphological cause, iii) human cause, and iv) physical cause

Geological Causes

Geological cases are associated with the weak, sensitive, sheared and jointed materials in the internal part of earth surface. There are adversely oriented mass discontinuity like bedding and schistocity, and structural discontinuity (e. g., fault, contact and unconformity etc.). Large number of thrusts and faults are positioned from east to west in the Himalayas range. Main frontal thrust (MFT) and main boundary thrust (MBT) are major active faults where weak and fragile zone exists (Thapa & Bhandari, 2019; Dhital et al., 1993). Small and large landslide can be observed along these faults. Likewise, divergence in permeability plays important role in bringing landslide incidence in the earth surface.

Morphological cause

Fluvial, glacial and wave erosion of slope toe are the main morphological reasons which

can be visibly observed in the earth surface. Slope plays fundamental role in landslide. Various study showed that slope gradients of 30 to 40 degrees are most likely failure zone in the Nepal Himalayas. Tectonic or volcanic uplift, glacial rebound, lateral erosion, sub-terrain erosion and vegetation loss are also causes of morphology.

Human cause

Construction of roads, irrigation channel and reservoirs, mining, artificial vibration, water leakage from utilities are some examples of human causes leading to landslide. Deforestation is the main source of erosion and landslide in the mountaineering country like Nepal. Vegetation also plays a vital role in determining slope stability and soil erosion processes that protect top soil in the monsoon season. Due to high demand of agricultural land the forest cover area has been shrinking. Similarly, excavation of slope and its toe is also another factor for occurring landslides during developmental works.

Physical Cause

Physical causes include intense rainfall, continued exceptional precipitation, rapid snow melt, rapid floods and tides. Other hazards such as earthquake and volcanic eruptions push out the landslides risk. Nepal earthquake 2015 brought many landslides in the high mountain areas. It was found that earthquake induced landslides had blocked the course of Marshyandi river near Pisang settlement in Manang district of Gandaki province (Raya, 2020). There is also important role of weathering process by freezing, thawing, shrinking and swelling to form the landslide in the Himalayan areas. This process disintegrates the rock structure and soil.

Intense rainfall strongly contributes in the occurrence of frequent landslide. Water penetrates rock joints and makes hydrostatic stress to loosen discontinuity of rock structure. Almost all events of landslide occurs in the monsoon season in Nepal induced by climatological factor. In 1993, cloudburst rainfall (70 mm/hour) was responsible for widespread slopes failure in the Kulekhani catchment. In Kabilas VDC of Chitwan district many large scale landslide occurred when the intensity of rainfall reached 80 mm/hour (Dixit, 2003). Likewise, the upper catchment area of Koshi river has been occurring the high degree of soil erosion and landslide where silt and sediments yield has observed round 19 m^3 /ha/year. Koshi disaster had created the huge catastrophic event in the downstream of Koshi river in 2008 (Sah, 2009).

Present scenario of Landslide

Slope instability plays vital role in arising landslide hazard in the mountain areas. About 1.8 million ha (13%) of land in the mountains is estimated to be severely degraded by landslides (CBS, 1994). According to UNDRR DesInvetar records and DRR portal of government of Nepal, about 990 people had died due to landslide hazard between 1971 and 2020. There were about 421 people injured and 183 people missing. Likewise, 107,259 people were affected during that period (Table – 2).

Table 2: Human effect by districts from landslide in Koshi province, 1971-2020

Districts	No. of Deaths	No. of Injured	No. of Missing	Affected people	Destroyed Houses	Damaged Houses	Economic Losses
Taplejung	247	72	49	9159	1048	869	403620905
Khotang	166	61	31	11239	356	20170	130360620
Okhaldhunga	104	55	21	4023	207	166	107687200
Sankhuwasabha	104	32	33	20156	292	485	78008160
Bhojpur	77	27	16	15837	609	51	76752380
Solukhumbu	70	28	11	6910	238	26	59772700
Ilam	67	13	3	3212	200	389	37521035
Panchthar	53	53	4	6593	188	85	19410760
Udayapur	45	33	15	6132	444	185	14873300
Terhathum	26	20	0	14105	212	46	10547975
Dhankuta	20	16	0	4523	497	680	2570000
Morang	7	2	0	3467	54	1	1089750
Jhapa	2	3	0	1862	66	383	0
Sunsari	2	6	0	41	5	3	0
Total	990	421	183	107259	4416	23539	942214785

Source: UNDDR DesInventar Database and DRR portal, Nepa1, 2021
Note: Database includes from January, 1971 to December, 2020

Human casualties from landslide are more prominent than other natural disasters during the five decades. Out of 11 hilly districts, Taplejung district has highest figure of human deaths and lowest casualty of human is in Dhankuta district during five decade period. Likewise, Khotang district is the second largest human casualty bearing districts. Terai based three districts (Jhapa, Morang and Sunsari) have very low effects of landslide because very few northern parts of these districts are located in the Siwalik and Mahabharat range. It had completely destroyed 4416 houses, and 23,539 were partially damaged between 1971 and 2020 in Koshi province. Similarly, economic value with the amount of Rs. 942,214,785 was lost in same period (Table–2).

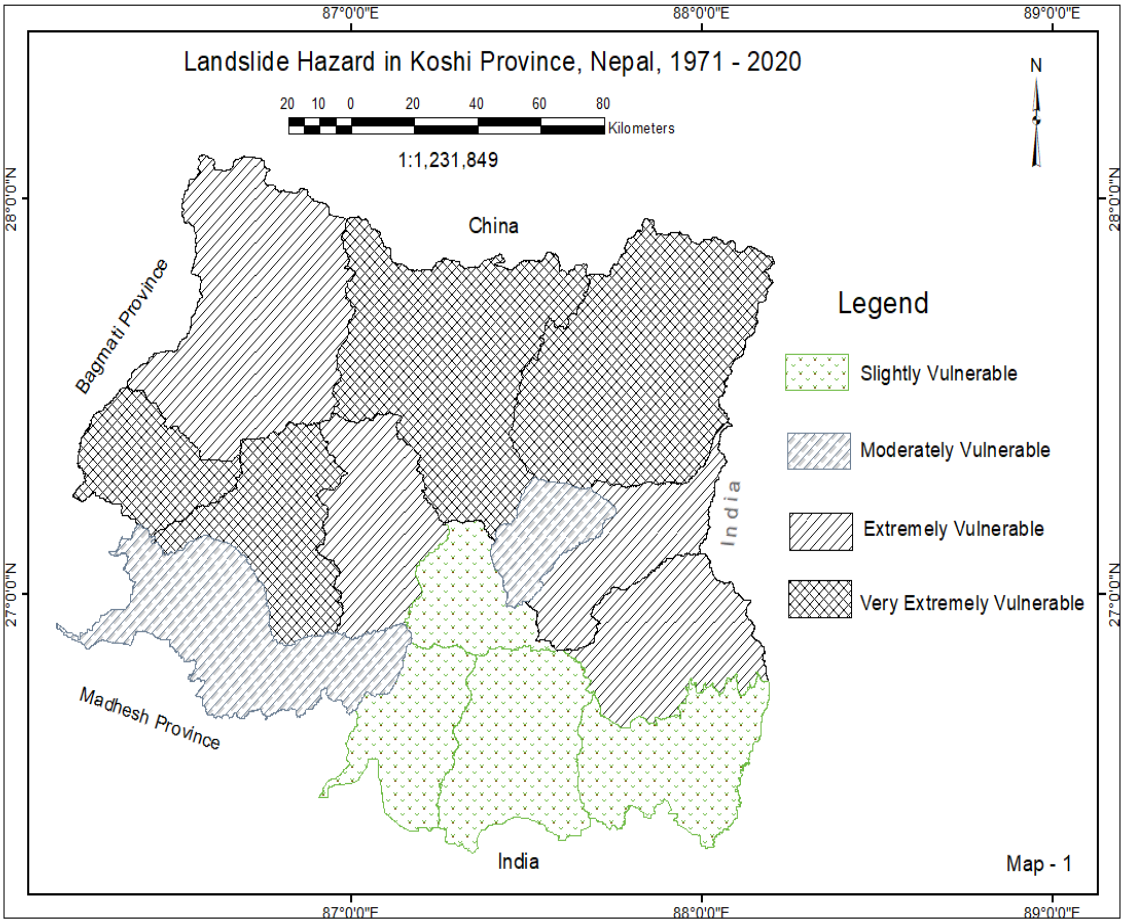
There were the cases of large scale destruction of houses of local residence in the Koshi province in the fifty years. Khotan district had the highest record of landslide effect where altogether 1048 numbers of individual houses were totally destroyed and 896 houses were destroyed to some extent. Moreover, Okhaldhunga, Udaypur and Taplejung district have followed such situation with the large numbers of houses destruction.

The five decade recorded data showed that the 14 districts were affected differently. These are broadly classified into four groups from vulnerability point of view based on the figure of human casualty due to landslides (Table - 3).

Table 3: Classification of districts by degree of Vulnerability

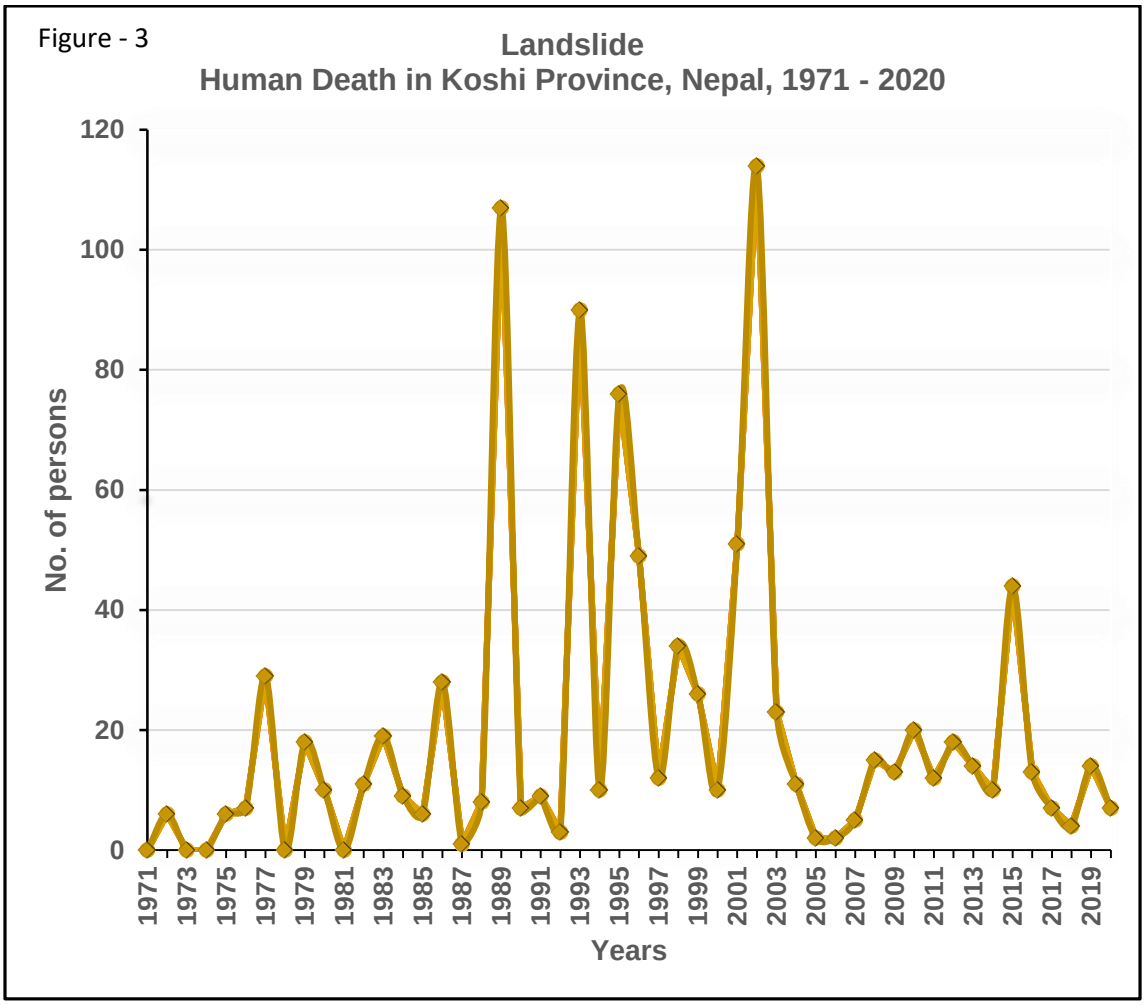
SN	Categories	Districts
1	Very extremely vulnerable	Taplejung, Khotang, Okhaldhunga and Sangkhuwasabha
2	Extremely vulnerable	Bhojpur, Solukhumbu, Ilam and Panchther
3	Moderately vulnerable	Dhankuta, Terhathum and Udayapur
4	Slightly vulnerable	Jhapa, Morang and Sunsari

The table 3 shows that four districts - Taplejung, Khotang, Okhaldhunga and Sangkhuwasabha, are very highly vulnerable districts while other four districts - Bhojpur, Solukhumbu, Ilam and Panchther, can be recognized as high vulnerable districts from landslide hazard. These 8 districts are mainly hazardous districts in the Koshi province of Nepal. Likewise, three districts - Dhankuta, Terhathum and Udayapur, are moderately vulnerable districts in the hills and mountain region. While Terai based three districts - Jhapa, Morang and Sunsari, are slightly vulnerable ones. The districts are shown in the map of the province below.



The distribution pattern of landslide hazard in Koshi province can be clearly observed in four spatial areas. Extreme vulnerability is concentrated in the high mountain districts (Map - 1). In every monsoon period landslide creates havoc and miserable situation to the local inhabitants due to torrential rain in short time of period.

Figure - 3



This study shows the trend of human deaths and other losses affected by landslide over five decades, between 1971 and 2020 years in Nepal (Figure 3). The maximum number of deaths occurred in 2002 (about 114 people) while the minimum number of deaths was recorded in 1987 (only 1 person). The effect of landslide on human varies year by year. It has sharply increased the human deaths in 1989, 1995, 2002 and 2015 year. Therefore, the landslide is constantly triggering the human hazards in term of loss of lives and physical properties every year.

Despite this, some never-ending landslide events have adversely hampered to the local residence as well as national economic development. For examples, landslide along Munglin - Narayanghat highway; Shiddababa landslide along Butwal - Palpa route in Rupandehi district; Jure landslide on the way to Kodari in Sindhupalchock district and Ramche landslide on the way to Dhunche from Trisuli route in Rasuwa district are frequently blocking the highway and are

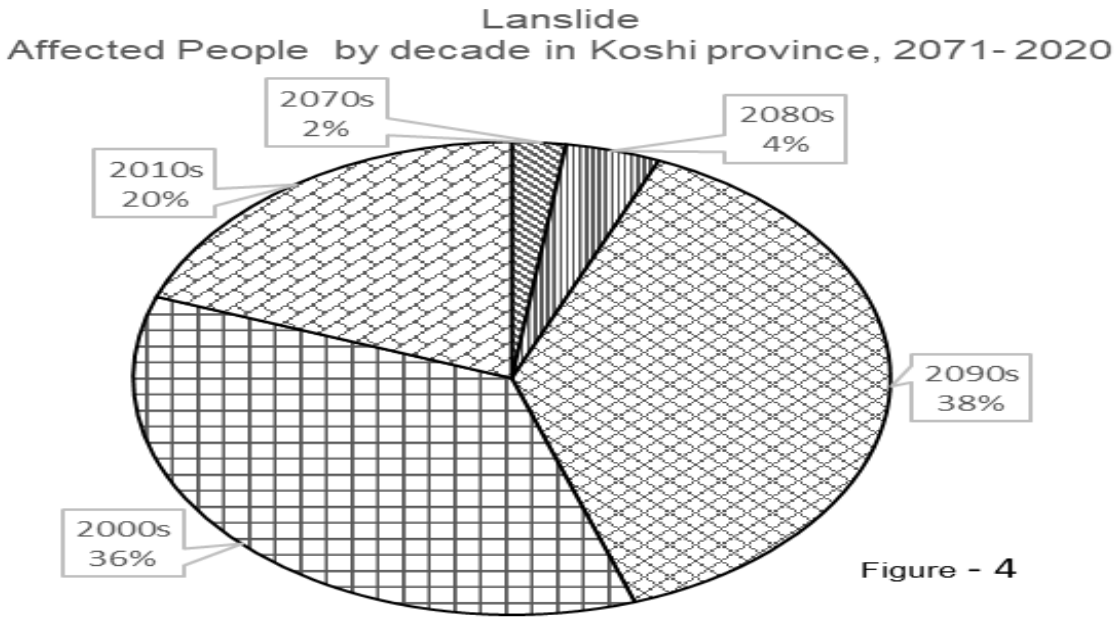


Figure - 4

immensely affecting the surrounding settlements in rainy season each year. In addition, the landslides of Hangdewa and Harewa in Taplejung district have been frequently disturbing the human lives and destroying physical properties since 1964 (Raya, 2011).

Table 4 and figure 4 show that the decades of 1990s and 2000s have highly impacted on local residence from risk of landslides in the Koshi province between 1971 and 2020 while the lowest impact was observed in 1970s. In the decades of 1980s and 2010s there was moderate impact of landslide hazard in Koshi province.

Table – 4: Landslide impact on human life by decade in Koshi province, 1971-2020

Years	Death	Injured	Missing	Affected People	Destroyed Houses	Damaged Houses	Economic loss
2070s	76	28	8	2,459	140	2	100,000
2080s	196	53	6	4,356	409	142	6,651,000
2090s	319	119	43	41,169	1,497	518	118,101,085
2000s	256	128	96	38,473	1,152	21,127	222,084,300
2010s	143	93	30	20,802	1,218	1,750	595,278,400
Total	990	421	183	107,259	4,416	23,539	942,214,785

Source: UNDDR DesInventar Database and DRR portal, Nepal, 2021

Conclusion

Landslide disaster has been affecting the large number of human lives and huge loss of properties every year. Geological, morphological, human and physical causes are common factors for triggering landslide in Nepal. Because of such causes, the landslide disaster has greatly recorded around 990 human life fatality in 1971- 2020. Likewise, about 107,259 number of people has been largely affected by this disaster in same period. The maximum number of deaths was 114 people in 2002 and the minimum deaths was 1 in 1987 over fifty years. Of total 14 districts, it has found that four districts are very extremely vulnerable like Taplejung, Khotang, Okhaldhunga and Sangkhuwasabha while other four districts - Bhojpur, Solukhumbu, Ilam and Panchther are extreme vulnerable districts in Koshi province, Nepal. Moreover, the number of human deaths caused by landslide has different in each decade over fifty year. The high degree of impact was in 1990s and 2000s decades. There might be the high risk forever to great loss of human lives and infrastructure every monsoon period. To reduce the disaster of mountain people and environment, planned settlements and physical constructions with due consideration of adaptation strategy in the future. In depth field study of landslide impact has to be further investigated to identify the real situation on the ground which is serious concern for primarily bringing susceptibility to our life in the context of unique geographical and climatic conditions of Nepal.

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