A study on Landslides in Himalayan Mountains

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Abstract: *This work explored the spatial and temporal dimensions of landslide in Himachal Pradesh with a focus on identifying critical zones of highly concentrated landslide activities. The results shows that slope failure activities show increasing trends and there is not only upward rise in annual and decadal frequency of landslides but the number of years with exceptionally high occurrence during each decade have also increased. The natural conditions including unstable steep slopes, weak rock structure and intense rainfall are main reasons for slope failure in the state.*

Key words: *Himalayan, Landslides, mountain system, Beas river valley, disastrous natural events.*

1. INTRODUCTION:

Landslide refers to down slope movement of surface material. Such phenomena result from several natural causes such as rainfall, seismic tremors, overburdening by rock material, removal of basal lateral support, loosened soil structure, blockage of drainage etc. as well as human induced/created causes. The term landslide encompasses all varieties of mass movements consisting of different types of rock fall, topple and debris flow (Varnes, 1984) etc. under the influence of gravity. The failure of shear strength or exceeding shear stress leads to down slope movement of surface material (Hyndman & Hyndman, 2009. Landslide is a short lived and suddenly occurring phenomena that cause considerable loss of life, widespread damages to infrastructure and facilities. However it may have had a long gestation period and the natural processes that result in a landslide may have been underway for a considerable time before the landslide actually occurs. Prolonged human activity of a detrimental nature may also lead to landslides.

The state of Himachal Pradesh is inherently prone to disasters, more so as it is a part of the Himalayan mountain system. The state has a long history of disastrous natural events (Chandel and Brar, 2010, 2011, 2012) and frequent natural disasters of varying intensity hamper the development of the state and strain the state exchequer (Planning Commission, 2005). This work explores the spatial and temporal dimensions of landslide as a disaster in Himachal Pradesh with a focus on identifying critical zones of highly concentrated landslide activities.

2. HISTORICAL PERSPECTIVE ON LANDSLIDES IN HIMACHAL PRADESH:

Landslides have an established history in the state; however the information on such disasters is very limited and restricted to the areas of population concentration or along the major transportation networks. The gazetteer of the Simla Hill State (Punjab Government, 1910) mentioned numerous landslides induced by an earthquake in 1803. These landslips blocked the river Satluj and river Giri and created huge dams. The bursting of dams led to large scale destruction in Bilaspur and Sirmaur districts. Apart from these events, some folk tales also corroborate the landslide activities in upper Beas River valley in Kullu. One such location is near village Bandrole, about 13 km. north of Kullu town, where according to a legend a massive landslide buried an entire village (Gardner, 2002).

The records reveal that 1905 Kangra earthquake induced numerous landslides in the Beas river valley between Kullu and Manali (Punjab Government, 1926). Chander (1989) in his PhD thesis mentioned the occurrence of 33 landslides on Kalka-Rampur highway and 3 landslides on Mandi-Manali highway during 1935-1947. The Tribune, June 10, 1935 reported many landslides near Barog on Kalka-Shimla highway that isolated areas of Solan and Dharampur from the other markets and led to the shortage of food products. During late 1950s, two landslides occurred five and half kilometers south of Kumarsain in Shimla district on Shimla-Rampur highway, due to heavy rainfall (The Tribune, 4 & 5 June 1957); one in Shimla town near Jakhu (The Tribune, 15 September 1957); and at various places on Kalka-Shimla highway (The Tribune, 18 September 1957). The Tribune, 11 June 1958, reported landslide near Aut in Mandi district along the Mandi-Manali highway in which road workers were caught under the falling mass of rock claiming two lives. Another landslide occurred in Kullu due to heavy rainfall (The Tribune, 19 July 1958).

A huge landslip occurred in 1963 on Bilaspur- Chandigarh highway at Gambhar in Bilaspur district: "Landslides in hills are common, but there is something unusual in the cave-in of a 2000-f. stretch of the recently-constructed Shimla Nangal Road in Himachal Pradesh. The "sunken" portion of the road settled at about 800 feet below its alignment… The site is 16 miles, 600 yards from Bilaspur, and few hundred yards from the bank of Gambheir, a tributary of the Sutlej, near Charole village... The mishap occurred on the night of April 1 shortly before midnight" (The Tribune, 9 April 1963). As per the news report, the truck drivers were stopped few hundred yards

from village Charole by "a chunk of a hillock which had just started to fall… another landslide began in front of them". According to an eyewitness "we found ourself going down rapidly, but without any jerks… The movement was then stopped and they found

3. OBJECTIVE OF STUDY:

To study the landslide events/happenings during last 4 decades in Himalayan Mountains

4. RESEARCH METHODOLOGY:

All available information on historical scenario has been collected from different sources. This is followed by spatio-temporal patterns of landslides for the period 1971-2016 for which continuous data has been collected from various secondary sources i.e. daily news reports from newspaper 'The Tribune'. The news reports from which the data on landslide events is compiled contain an element of locational bias in favor of areas of dense population or transport networks; it is likely that some events that occurred away from such areas were not reported and hence do not form a part of this analysis.

6. DATA ANALYSIS AND INTERPRETATION:

Table 1: Area under Landslide Hazard in Himachal Pradesh District

District		Area under Landslide Hazard Risk (per cent)			Total
		Severe to Very High Risk	High Risk	Moderate to Low Risk	
1	Kullu	33.70	65.04	1.20	99.94
2	Chamba	33.28	60.11	5.51	98.90
3	Solan	29.11	58.53	8.22	95.86
4	Mandi	25.01	51.11	21.34	97.46
5	Bilaspur	18.91	73.73	7.27	99.91
6	Shimla	17.79	66.65	15.28	99.72
7	Kinnaur	13.73	78.39	7.88	100
8	Sirmaur	3.46	65.83	22.39	91.68
9	Kangra	2.19	65.91	21.97	90.07
10	Lahaul & Spiti	0.93	85.62	13.43	99.98
11	Una	0.13	44.96	34.28	79.37
12	Hamirpur	0.00	77.36	18.55	95.91
HIMACHAL PRADESH		**14.27**	**70.07**	**13.08**	**97.42**

Source: *Government of India, 2003, Landslide Hazard Zonation Atlas of India*

The annual distribution of landslide events for the period 1971-2016 displays the steadily rising trend in landslide frequency (figure 1) and 919 landslide events (table 2) were recorded in Himachal Pradesh. The distributional trends depict a slight decline from late 1970s till late 1980s; after this there is a rise in the frequency patterns. The intensification is not just in terms of the frequency of landslides, there has been an increase in the number of years that record a high number of events. The 1970s witnessed 164 incidents of landslides with an annual average of 18.22 events per year, which accounts for 18 percent of the total events that took place during 1971-2009. During 1980s landslide frequency was at an all time low as this decade accounts for about only 62 (6.7%)

Landslide events and annual average was just over 6 events per year. The decadal frequency in most of the districts has been on the rise after 1980s. In 1990s, 219 events (23.8%) at the annual average of about 22 events were recorded in the state. There was further increase in landslide events during 2000s (table 2) which recorded 474 landslides having annual average of 47 events per year, accounting for over 51 % of total events. 2010-2016 recorded 619 landslide events having annual average 73.70.

Table 2: Decadal Distribution of Landslides (1971-2016)

S.N.	Decade	Total Landslides	Per cent	Decadal Average	Landslide Character
1	1971-1979	164	17.84	18.22	High landslide activity
2	1980-1989	62	06.75	06.20	Declined activities
3	1990-1999	219	23.83	21.90	Increase in landslide activities
4	2000-2009	474	51.58	47.40	Intensification over time & space
5	2010-2016	567	73.50	68.77	Intensification over time & space

Source: compiled from The Tribune, 1971-2016

The district wise distribution of landslides for the period 1971-2009 shows that there has been continual rise in landslide activities, particularly in post 1980 decades (table 3). During 1970s major landslide prone districts included Shimla (30.49%), Solan (23.17%), Mandi (12.20%) and Kinnaur (10.37) while in 1980s, Mandi (19.35%), Una (17.74%), Shimla (14.52%) and Solan (11.29%) were the most affected districts. During 1990s, Shimla (25.11%), Solan (14.15%), Mandi (12.33%) retained the status of being the most landslide prone districts while Chamba (11.87%) emerged as another landslide prone area. Similarly in 2000-2009, Shimla (20.04) was again the most landslide prone district. Kinnaur (17.93%), Solan (13.08%), Sirmaur (11.39%) and Chamba (10.34%) were other most landslide prone areas. Landslide occurrence during these 39 years exhibit that four districts, namely, Shimla, Solan, Kinnaur and Mandi account for more than 62 per cent of total landslide occurrences in the state. Shimla with 209 events accounts for over 22.74 per cent of total landslides incidents followed by Solan (15.02%), Kinnaur (13.38%) and Mandi (10.77%).

Table 3: District-wise Decadal Distribution of Landslides (1971-2009)

Sr. No.	Districts	1971-1979	1980-1989	1990-1999	2000-2009	2010-16	Decadal Total (per cent)
		Events (per cent)	Events (per cent)	Events (per cent)	Events (per cent)	Events (per cent)	
1	Shimla	50 (30.49)	9 (14.52)	55 (25.11)	95 (20.04)	138 (24.33)	**347 (23.35)**
2	Solan	38 (23.17)	7(11.29)	31 (14.15)	62 (13.08)	54 (9.5)	**192 (12.92)**
3	Kinnaur	17 (10.37)	3(4.84)	18 (8.22)	85 (17.93)	87 (15.34)	**210 (14.13)**
4	Mandi	20 (12.20)	12 (19.35)	27 (12.33)	40 (8.44)	64 (11.28)	**163 (10.96)**
5	Chamba	4 (2.44)	6 (9.68)	26 (11.87)	49 (10.34)	53 (9.34)	**138 (10.77)**
6	Sirmaur	7 (4.27)	0	3 (1.37)	54 (11.39)	22 (3.88)	**86 (5.78)**
7	Kangra	4 (2.44)	5 (8.06)	10 (4.57)	38 (8.02)	61(10.75)	**99 (6.67)**
8	Kullu	8 (4.88)	3 (4.84)	15 (6.85)	23 (4.85)	31 (5.46)	**54 (3.63)**
9	Bilaspur	12 (7.32)	2 (3.23)	19 (8.68)	7 (1.48)	12 (2.11)	**52 (3.49)**
10	Lahaul & Spiti	2 (1.22)	1(1.61)	7 (3.20)	12 (2.53)	15 (2.64)	**37 (2.39)**
11	Hamirpur	2 (1.22)	3 (4.84)	6 (2.74)	7 (1.48)	28 (4.93)	**46 (2.48)**
12	Una	0	11 (17.74)	2 (0.91)	2 (0.42)	2 (0.35)	**17 (1.14)**
Total (percent)		**164 (100)**	**62 (100)**	**219 (100)**	**474 (100)**	**567 (100)**	**1486 (100)**

Table 4: Seasonal Distribution of Landslide (1971-2009)

Decade		Season Distribution			Total Per cent
Winter Jan-Mar		Pre-Monsoon Apr-Jun	Monsoon Jul-Sept	Post- Monsoon Oct-Dec	
1	1971-1979	14 (08.53)	19 (11.59)	129 (78.66)	02 (01.22)	**164 (17.84)**
2	1980-1989	04 (06.45)	01 (01.61)	53 (85.49)	04 (06.45)	**62 (06.75)**
3	1990-1999	20 (09.13)	05 (02.28)	169 (77.17)	25 (11.42)	**219 (23.83)**
4	2000-2009	30 (06.33)	82 (17.30)	352 (74.26)	10 (02.11)	**474 (51.58)**
Total		**68**	**107**	**703**	**41**	**919 (100)**
Per cent		**07.40**	**11.64**	**76.50**	**04.46**	

7. SEASONALITY OF LANDSLIDE OCCURRENCE:

Intense and torrential rains are the principal cause of slope failure and majority of landslides in Himachal Pradesh occur during the monsoon season (table 4). During 1971-2009, 703 (76.50%) landslide events occurred during the monsoon season. The pre monsoon showers were also responsible for about 107 (11.64%) events of landslides while winter rains and snowfall during early months of the year cause over 7 per cent of total landslides.

8. CONCLUSION

The occurrence of landslides in Himachal Pradesh is a frequent and wide spread activity. Slope failure activities show increasing trends and there is not only upward rise in annual and decadal frequency of landslides but the number of years with exceptionally high occurrence during each decade has also increased. Landslide occurrence

during last four decades has been very high in Shimla, Solan, Kinnaur and Mandi districts. The high intensity rainfall, particularly in monsoons, is one of the chief triggering factors for such incidents.

The natural conditions including unstable steep slopes, weak rock structure and intense rainfall are main reasons for slope failure in the state. However, the vulnerability in these geologically young and unstable steep slopes has increased due to anthropogenic activity such as road construction, expansion of settlements and other allied developmental activities, deforestation and changes in agriculture pattern. This is particularly true for landslide prone areas of Kinnaur, Chamba, Shimla, Kullu and Lahaul & Spiti districts where large scale road construction and widening activities are under process to facilitate hydro-power projects and transportation facilities.

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