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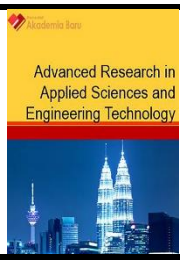

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Landslide Killing Himalayas: Collective Study on Causal Factors and Possible Remedies

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ABSTRACT

Soil is naturally available material used for construction all over the world. When this material available in form of natural slope can cause landslide. Purpose of this study is to understand behavior of different causal factor of landslide at Himachal Pradesh and then suggest some remedial measure. To fulfill this, aim five-year data of precipitation for every district is collected from metrological department and analyzed. Data of earthquake activities is also collected. Work done by different author in this area is analyzed thoroughly. It is found that the change in climatic conditions such as increase in precipitation over years, earthquakes and anthropogenic interference has increased the landslide susceptibility of area. Remedial measure suggested as use of landslide susceptibility zonation map future land use pattern, use of advance technology like soil nail and gabion wall and use of numerical modeling to analyze slope stability.

Keywords:

Land slide, earthquake, geotechnical investigation, landslide susceptibility zonation, precipitation

1. Introduction

Landslide is common word used to describe various type of slope movement. Vrane in 1978 has classified landslide as flow, falls, spreads, translational slides, topples and rotational slide. Himachal Pradesh is hill state of India and famous tourist attraction center [1]. According to disaster policy of Himachal landslide is one of main hazard in the state. Mountains of Himalayas are geologically seen as very young mountains. In these young and not so stable slope events of landslide are increasing due to activities of human like cutting of road, deforestation and changes in agriculture crops requiring more intense watering [2]. Research done by Surya Prakash has clearly shown that west and North West area of Himalayas suffer more landslide compare to northeast and south India. In his data collection from 1800 to 2011 he had found that total of 3971 people loss their life out of which 1946 were from west and north west region of Himalayas [3]. Global pattern of loss of life from landslide found that maximum number of loss in term of life due to landslide is found to be occurring along Himalayan arc and china [4]. Objective of present study is to understand causal factors effecting

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landslide in the state and provide feasible solutions for landslide as there is need of more scientific and engineered study of landslide problem at Himachal Pradesh.

2. Factor Effecting Landslide

Popescu in his work has shown importance of understanding caustic factor for finding best cost-effective solution for landslide problem. There is list of causal factors made by IUGS WG/L Commission on Causes of Landslides in well-arranged order. There is two type of casual factor affecting the landslide: preparatory causal factor, triggering causal factor. As name signify preparatory casual factor responsible for making slope vulnerable to landslide whereas triggering factor initiate the movement [5]. Most of time there are several causal factors responsible for landslide such as ground condition, geomorphic process, physical process, manmade process. In most of landslide triggering factor is precipitation. Water cause increase in pore water pressure in soil which decrease shear resistance resisting force of soil. If it is present in rock it may get inside discontinuity and can generate hydrostatic pressure [6].

Table 1
brief list of casual factors responsible for landslide

Ground conditions	Geomorphological processes	Physical processes	Man-made processes
1.Plastic weak material 2.Sensitive material 3.Collapsible material 4.Jointed or fissured material 5.Sheared material	1.Vegetation removal (by erosion, forest fire, drought) 2.Tectonic uplift 3.Volcanic uplift 4. erosion	1.Intense, short-period rainfall 2.Rapid melt of deep snow 3.Prolonged high precipitation 4.Earthquake 5.Volcanic eruption	1.Excavation of slope or its toe 2.Draw down of reservoirs 3.Irrigation 4.Water leakage from services 5.deforestation

2.1 Rainfall Behavior in the Area

Number of case study in area has shown that rainfall was triggering factor for landslide in Himachal Pradesh. it was observed that normal annual rainfall of Himachal Pradesh was 1267 ± 375 mm during period of 1971-2014. Average 66 rainy days observed through year. It was observed that rainfall more than 1000 mm which having probability of occurring more than 75% was at sixteen out of forty stations [7]. Study of 1951 to 2005 observed that maximum value of mean annual rainfall is located at Dharmashala region with intensity of 2923.4 mm and lowest mean annual rainfall is at Sangla having intensity of 752.3mm is found increase in pattern of heavy rainfall event in Palampur region. It is observed that rainfall intensity is increasing in region where as number of rainy day is decreasing. Maximum contribution of precipitation in state is by monsoon rain (78.55%), whereas pre-monsoon contributes (9.17%), winter rains which generally occur due to western disturbance is 8.06% and post monsoon is (4.21%) [8] Western Disturbance is rainfall observed in northwest part of india during winter it is originating in the Mediterranean Sea and the Atlantic Ocean. Winter precipitation is found to be more at higher altitudes as compared to lower altitudes. During his research done in 2015 low presipitation is recorded in November and December month lead to bad effect to winter crop and more air pollution in city [9]. Decreasing trend is seen in frequency of WDs

over Himachal Pradesh in his research of time period 1997-2007 [10]. Five-year data (2014-2018) of rainfall of every month has been collected from metrological department, it has been found that Kangra have maximum rainfall intensity of 924 mm in august 2018.it is also found that overall rainfall of state has shown increasing trend in year 2018 [11].

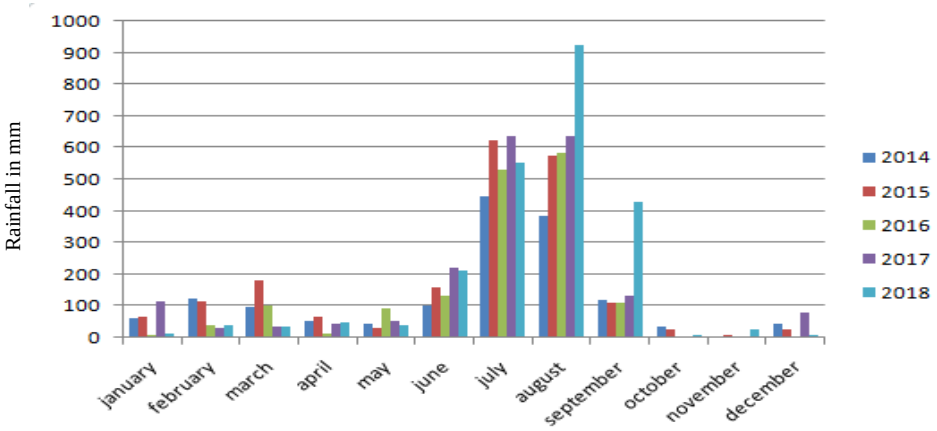

Fig. 2. Kangra, H.P rainfall data from 2014 to 2018

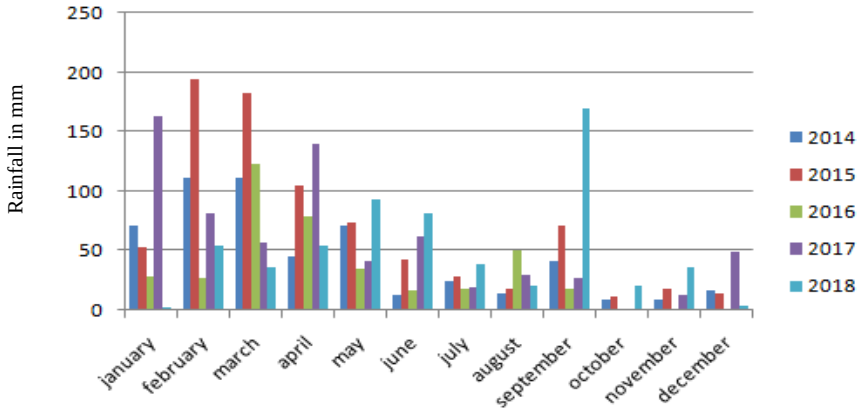

Fig. 3. rainfall data of Lahul and spiti 2014-2018

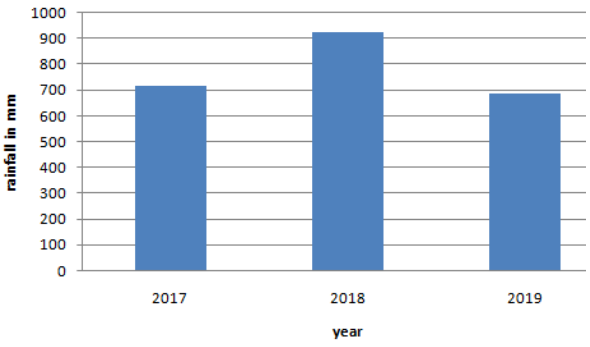

Fig. 4. showing monsoon rainfall intensity graph from 2017 to 2019

2.2 Seismic Condition of Area

When there is displacement of two block of rock along fault then earthquake happen .Level of magnitude and distance from epicenter give level of shaking at susceptible slope Material which is most vulnerable to earthquake induced landslide is weakly cemented rocks, granular man-made fill, residual and colluvial sand, granular deltaic deposits loess, high-indurated rocks with pervasive or prominent discontinuities, cemented soils, volcanic soils containing sensitive clay, granular alluvium[12]. According to earthquake hazard profile of state the tectonic features in the Himachal Pradesh include the Main Central Thrust and main boundary fault which are parallel to the strike length of Himalayas. The Jutogh Giri, Krol and Nahan thrusts also present in state. There is also presence of small faults, like Kaurik Fault due to which1975 Kinnaur earthquake happened. Kangra and Dharamshala has suffered biggest landslide of state in year 1905, having magnitude 8.0 in Richter scale. It has cause death of 20000 persons. more than 250 earthquakes have been seen having magnitude more than 4.0 in 90 years. 1906 kullu earthquake M 6.4 Kullu and 1975 Lahual-Kinnaur Spiti earthquake M 6.8 was also major earthquake in area. Kullu, Kangra, Hamirpur, Bilaspur, Una, Mandi, and Chamba, Districts lie in zone five. districts of Kinnaur Lahual and Spiti, Solan Shimla, and Sirmaur lie in zone four [2]

Roger used geodetic, historical and seismological data to identify segment of Himalayas that remain enraptured. It is found that out of fifteen segments ten segment of the Main Himalayan Thrust arc are found to sufficiently mature to generate earthquake of more than 8 Mw. Estimated death is more than 100000 due to increase in population and poor quality construction [13].

Table 2
list of earthquakes occurs in past

Earthquake	**Location**	**Magnitude**
4-April-1905 Kangra	320 18’00” 760 15’00”	8
28-Feb-1906 -Kullu	320 00’00” 770 00’00”	7.0
5-Feb-1930 -Shila Kiepr	310 42’00” 770 00’00”	5.5
22-June-1945 -Minu , Chmaba	320 36’00” 750 54’00”	6.5
10-July-1947 – Minu, Chmaba	320 36’00” 750 54’00”	6.2
12-August 1950 Minu, Chmaba	320 36’00” 750 54’00”	6.0
19-Jan-1975 Distt.Kinnaur	310 56’24” 780 31’48”	5.5
26-April-1986 Near Nag Dal	320 19’00” 760 24’00”	5.5
11-Nov-2004 Bharmour	32.442 N, 76.512 E,	5.1

3. Possible Remedy

Mitigation prevention and Preparedness are the techniques used by stated disaster management authority to avoid any hazard convert into disaster. in case of landslide hazard Role of vulnerability mapping is highly recommended to be used in mitigation process which is done by producing landslide vulnerability zonation map with help GIS software’s. Whereas use of remedial measure, improving existing infrastructure or replace old one is recommended in point of view of prevention. While in preparedness process use of early warning system, use of information technology, medical preparedness and training and mock drill is highly advised [2].

3.1 Landslide Susceptibility Zonation for Prevention

Landslide susceptibility is spatial prediction of landslide. To find place of landslide happening with help of various causal factors. There are different approaches for LSZ. But mainly these are classified as qualitative and quantitative approach which can be subdivided as distribution analysis Geomorphic Analysis Map Combination Approach Quantitative Approaches, Statistical Analysis, Probabilistic Approach, Distribution-Free Approaches [14].

Table 3
List of LSZ work in HP

	LSZ area	Method	Author
1	Dharmashala	Information value	Swatisharma, abhirishkumar
2	Nahan to Rajgarh	Machine learning	Vijendra Kumar Pandey,
3	national highway-154A	information value and frequency ratio	Kanwarpreet Singh Virender Kumar
4	between Giri and Tons Rivers	GIS based technique	Piyoosh Rautelal
5	Kullu district	Information value	Laxmi Devi Versain,
6	Kullu district	Various	Laxmi Devi Versain

In study conducted by Swati Sharma and AK Mahajan they performed landslide susceptibility zonation in Dharamshala region of district Kangra in Himachal Pradesh India. landslides were discovered and confirmed by Google Earth images. Various causative factors were selected road buffer lithology, slope, aspect, soil type density, major fault density, drainage land cover. Computation of total landslide pixels for every subclass as well as landslide pixel is done to find information value. Information value of every subclass is then used to attach layer using ArcGIS software and landslide susceptibility map was made as shown in figure. Out of total landslides 0.66 sq km, 0.65 sq. km landslide fall in very high susceptibility class [15].

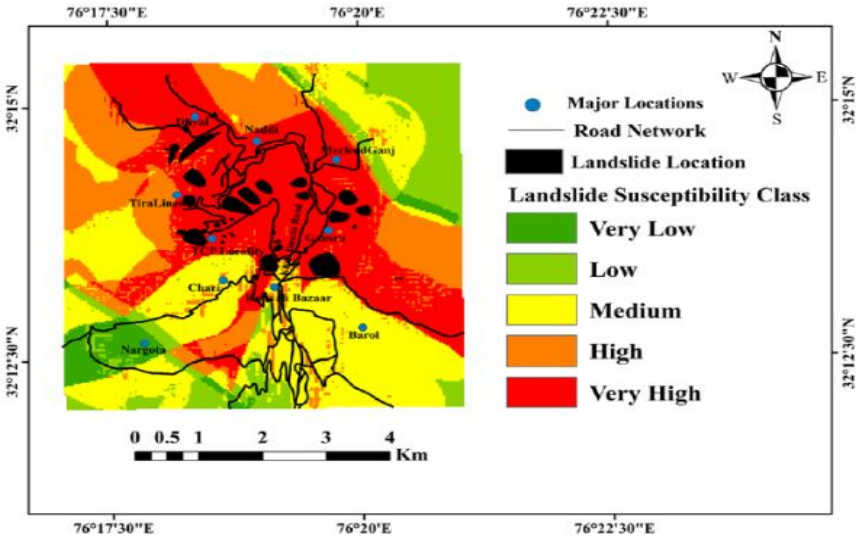

Fig. 5. Landslide susceptibility zonation map of Dharamshala

Also, in another study conducted by Panday, Vijandra developed landslide zonation map from Nahan to Rajagarh the point of this examination is to research the reasons for avalanches in the

Himalayan area and investigation of their sedimentary qualities. It is found that landslide frequently occur in lesser Himalayan range. In his study author find characteristics of the sediments and find best susceptibility zonation map by comparing results from different approach [16].

3.2 Feasible Solution for Mitigation

Pocescu has provided list of mitigation option which can be implemented in site, which include method like accepting it, avoiding it, decreasing its consequences, early warning system and monitoring landslide. Landslide can be prevented either by decreasing the driving force or increase in resisting force. Solution available can be broadly classified into 4 groups as; change in slope geometry, drainage, retaining structure, internal slope reinforcement [17]. Drainage is most important method in contrast to landslide remedy as presence of water in soil makes soil strength to lose its shear strength and increase its pore water pressure and slope to reduce its resisting force. Drain serves its function in reduction of pore water pressure [18]. In deep-seated landslide it is recommended to change its slope geometry. Also, it is observed that remedial measure is mostly used in combination. Debris flow which is very destructive can be mitigated by applying check dams. While different method of remediation is available it must be selected after looking at all aspect like engineering aspect, legal aspect, social aspect, environmental aspect. Ramli try to improve wall resistance against lateral movement with help of new interlocking systems in gabion wall. He suggested use of hexagonal shape block instead of regular rectangular shape as they found to be more stable in application of load experiment also show that less structural inertia is experienced by it which is 7.6% in first loading stage and 10.8% in last three loading stage. It is observed that gabion wall has more advantage as compare to retaining wall by acting many ways 1) to provide reinforcement which can handle many stresses like tension stress shear stress 2) they provide much batter load distribution as they not act to resist all forces and show some deformation. 3) They provide much batter drainage as they allow water to pass through it while resisting backfill [19]. Huang have discussed and provided remedy for completely destroyed slope which was present in Tiwan. Use of soil cement was prescribed in solution. Has used MCDA (multi-criteria decision analysis) approach method to find best remedial measure landslide occur at Hsinchu city in Tiwan. Site investigation was done to know geological, geographical information of site and testing was done to obtain all geotechnical properties of soil and then assessment of failure of slope is by preparing numerical model [20]. Use of numerical molding is seen on various case studies in Himachal Pradesh to find FOS or analyze stress distribution and deformation pattern during time of failure as observed in Kotropi remedial measure. This can be used to find effectiveness of remedial measure by analyzing old and new slope condition [21].

Table 4
A brief list of landslide remedial measures

Modification of slope geometry	**Drainage**	**Retaining structures**	**Internal slope reinforcement**
Removing or Adding material Reducing slope angle	Surface drains Drainage tunnels, Vacuum dewatering Electro-osmotic	Gravity- retaining walls Crib-block walls Gabion walls	Rock bolts, Micro piles, Soil nailing, Anchors, Grouting, stone columns, Heat treatment, Vegetation planting

4. Conclusion

Heavy Rainfall is found to be main trigging factor for most of landslide in Himachal Pradesh. Researches has shown high rainfall at Dehra, Dharamshala, Malan, Kangra, Nurpur, Palampu, Paonta, Nahan, Dhaulakuan Jogindernagar, Sarkaghat area. While decrease in precipitation due to western disturbance is observed. There is presence of main boundary fault (MBF) and Main Central Thrust (MCT), Krol, the Giri, Jutogh and Nahan thrusts small faults, like Kaurik Fault which make area highly susceptible to earthquake and earthquake induced landslides. Research has shown high probably of earthquake more than 8 Mw in future of slope which makes it important to ensure safety in term of earthquake induced landslide. Landslide susceptibility zonation is found to be very important tool for landslide mitigation as it give perspective for policy make for decision making and future land use pattern. There is need for preparation of more landslide susceptibility map focusing on specific areas. As widening of road network is going in large scale there is need of more research for understanding impact of anthropogenic and physical factor on landslides in area. Mostly retaining wall is used for stabilizing slopes in this area there is need of more advance methods. Use of gabion wall and soil nail with proper drainage system is highly suggested in area as most of landslide are caused due to high precipitation and triggered due to heavy rainfall.

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Appendix: List of landslides in past in Himachal Pradesh

Sn.	**Name**	**Reason**	**Date**	**Remarks**
1	Chirgaon	Cloudburst	11/81997	Kumar 2007
2	Sutlej Valley	Cloudburst	30/72000	Kumar 2007
3	Kullu	Flash flood	16/7/2003	Mazari and Sah 2004
4	Shimla	Heavy rainfall	15/8/ 2007	100 killed
5	Chittkul	Heavy rainfall	15/82007	65 killed
6	Nehrukund	Unknown	18/3/ 2008	25 Killed
7	Shimla	Continous rainfall	21/9/2008	42 killed, 13 houses collapsed
8	Kotropi mandi	Continous rainfall	13/8/2017	47 killed