LANDSLIDES IN HIMACHAL PRADESH ALONG THE NATIONAL HIGHWAY-3: SPATIAL PATTERN AND CHARACTRISTICS

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Abstract: Road network plays an important role in socio-economic development of the Himalayan regions. The roads of the Himalayan region are generally subjected to heavy slope failure events. Slope failure along highways is a crucial problem. The objective of this research paper is to analyze the spatial pattern and characteristics of landslide in the study area. The landslide inventory includes 302 landslides in the study area. In total, the mapped landslides occupy about 1.5 million square meter area which is 1.533 km². The smallest landslide area is 30 m² and the largest is 350000 m². The average is 5112.3 m², with a standard deviation of 27745.66 m², collectively the 302 landslides in the study area of around 1000 km² displaced 8.3 million cubic meters (m³) of slop material. According to the volume of the landslides 53% landslides are fairly large which have the debris 1000 to 9999 m³. The attribute data reveals that 81% landslides are still in active mode which is quite alarming and only 18% landslide sites have the mitigation measures which means still 82% landslide location need the mitigation measure to reduce the risk.
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Introduction

Landslides are significant hazards that can be disastrous to human life and property. Landslide is short lived and suddenly occurring natural phenomena, it is just a hazard when it occurs in an uninhabited place, however it turns into a disaster causing extraordinary landscape changes and destruction of life and property when it occurs in the vicinity of human habitation[1]. The term Landslide encompasses all varieties of mass movements consisting of different types of rock fall, topple and debris flow[2]. The failure of shear strength or exceeding shear stress leads to down slope movement of surface material[3]. Landslide is an important geological hazard that causes damage to natural and social environment[4]. Landslides occur when the land slope is unstable due to natural or anthropogenic activities[5].

Understanding the spatial distribution and characteristics of landslides is crucial for effective hazard mitigation and sustainable development[6]. Landslides are the most destructive phenomenon that occur in hilly regions frequently. The failure of slopes along highways results into heavy traffic jamming and causes inconvenience to the passengers[7]. In the disaster-prone map of the country, Himachal Pradesh has attained its position among first five states in respect of natural hazards, i.e. earthquakes, flash floods, landslides, avalanches and forest fire[8]. Roughly about 15% of India's landmass or 0.45 million km² area is prone to landslide hazard[9]. Himachal Pradesh has a road network of 33000 Kilometres and 80 percent of these roads are vulnerable to landslides[10]. The geographic location, climate and geophysical structure of a region greatly influence in determining the types of landslides[11].

The NH-3 is one of the major National Highways in the state which connects important tourist destinations Kullu and Manali. Most of the study area is lies in the Kullu valley. The Kullu Valley lies in the inner part of the Himachal Lesser Himalaya. The valley is structurally and lithologically controlled and carved by glacial and periglacial processes in the upper region and higher slopes of its tributary valleys, and by fluvial processes in the main valley corridor to produce a landscape of spectacular nature[12]. The landslide hazards, in general cannot be completely prevented however, the intensity and severity of impacts of the hazards can be minimized if the problem is recognized before the development activity[13]. As Kullu and Manali are the main tourist attraction the large number of economic activities and ongoing development programme like road widening and other anthropogenic activities have made the area more vulnerable to landslides.

Study Area

The study area situated in Mandi and Kullu districts of Himachal Pradesh between 76°89′ and 77°28′ East longitude and 31°61′and 32°39′ North latitude (fig.1). To extract the stretch in the Beas valley 5-kilometre buffer have been taken along the both sides of the Highway. The total study area is around 1000 km². The national highway from Mandi to Manali is the NH-3 (Old NH-21) till the Atal Tunnel whereas some stretch along Leh-Manali highway till Marhi has also been taken because six very large landslides occurred in this region near Rohtang pass. The study area is drained by the Beas River and its tributaries. A Dam is also constructed on Beas at Pandoh near Mandi. The physiography of the area is very diverse. The height near Mandi is below 1000 meter, whereas it is above 3500 meters near Manali with snow peaked mountains.

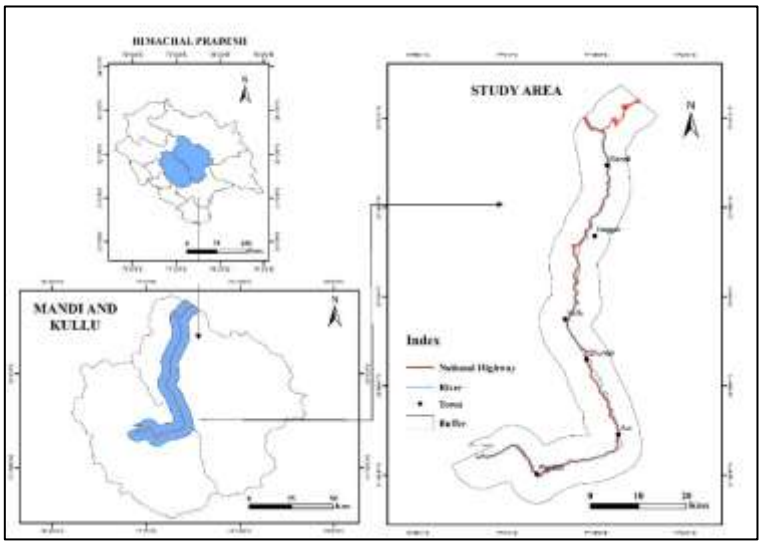

Figure 1; Study Area

Database and Methodology

In order to show the spatial pattern of the landslides in the study area the point data of landslide events has been used which is obtained from the Bhukosh portal of the Geological Survey of India (GSI). The digital elevation model (DEM) is extracted from The Shuttle Radar Topography Mission (SRTM). This dataset provides elevation values at 30-meter resolution. In order to show the characteristics of the landslide events the classifications provided by the National Institute of Disaster Management (NIDM) has been used. The landslide characteristics graphs were prepared by the attribute data by using the vector layer processing in Arc GIS software.

Results and discussion

Spatial distribution

The secondary data from the Bhukosh portal of the Geological Survey of India has been used to prepare landslide inventory. The landslide inventory includes 302 landslides in the study area (Fig. 1). The landslide data was collected in four years (2016 to 2020) by the Geological Survey of India team[14,15,16,17,18]. The oldest landslide in the data is from 1990 year and the recent most is from the year 2017. This detailed landslide inventory with the attribute data from Bhukosh portal of Geological Survey of India have been used to define the Landslide characteristics and spatial distribution of landslides in the study area.

The landslide map (Fig. 2) of the study area showing that the there is a continuous chain of landslides along the highway in the Beas River valley, landslides are mostly concentrated between Pandoh dam and Aut as well as near Kullu town and on the Leh-Manali road between Marhi and Gulaba near Rohtang pass.

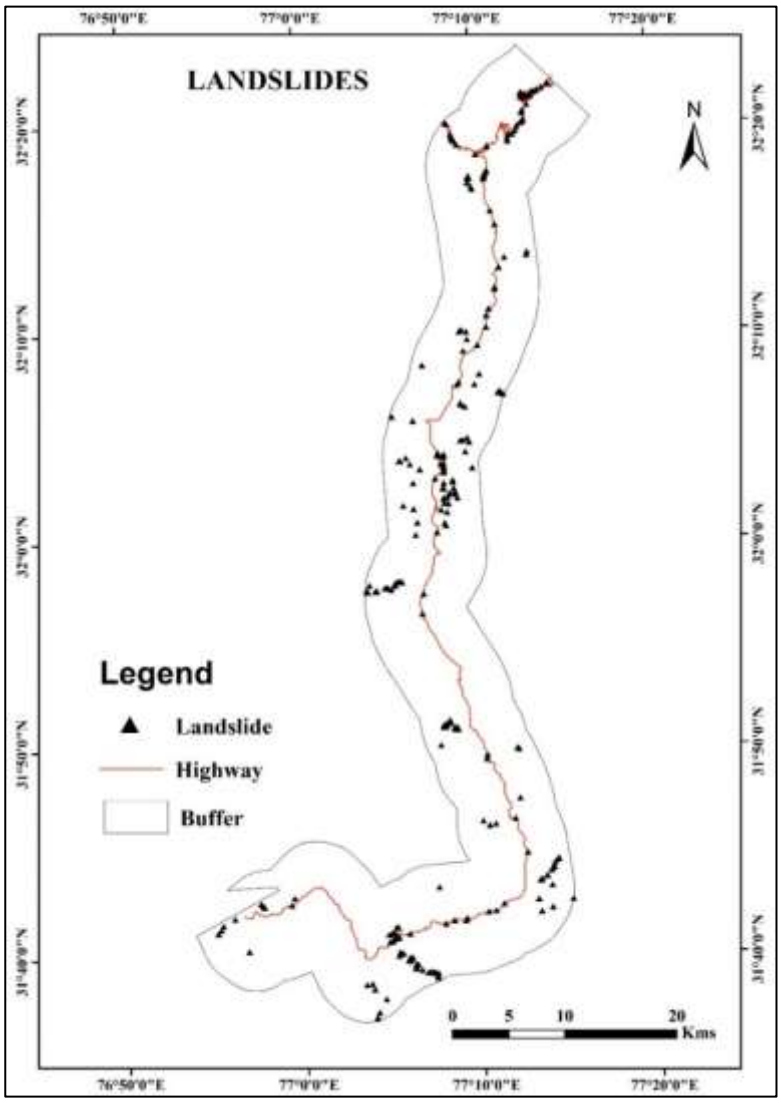

Figure 2; Landslides Inventory

Landslide characteristics

All landslides were classified according to the National Institute of Disaster Management report[19]. According to the attribute data 65% of the landslides occurred in debris material which is the mixture of fragmented rocks (fig.3) following with 21% of rock material.

In total, the mapped landslides occupy about 1.5 million m² area which is 1.533 km². The smallest landslide area is 30 m² and the largest is 350000 m². The average is 5112.3 m², with a standard deviation of 27745.66 m². Collectively the 302 landslides in the study area of around 1000 km² displaced 8.3 million cubic meter (m³) of slop material. The smallest landslide displaced only 40 m³ of material, the largest around 1750000 (1.75 million) m³. The average is 27707.7 m³, with a standard deviation of 149332.3 m³. According to the volume 53% landslides are fairly large which have the debris more than 1000 cubic meter following with 33% Small landslides, 10% Large Landslide (fig.4). Only 4% landslides are in very large category from which 50% occurred between Gulaba and Marhi near Rohtang pass.

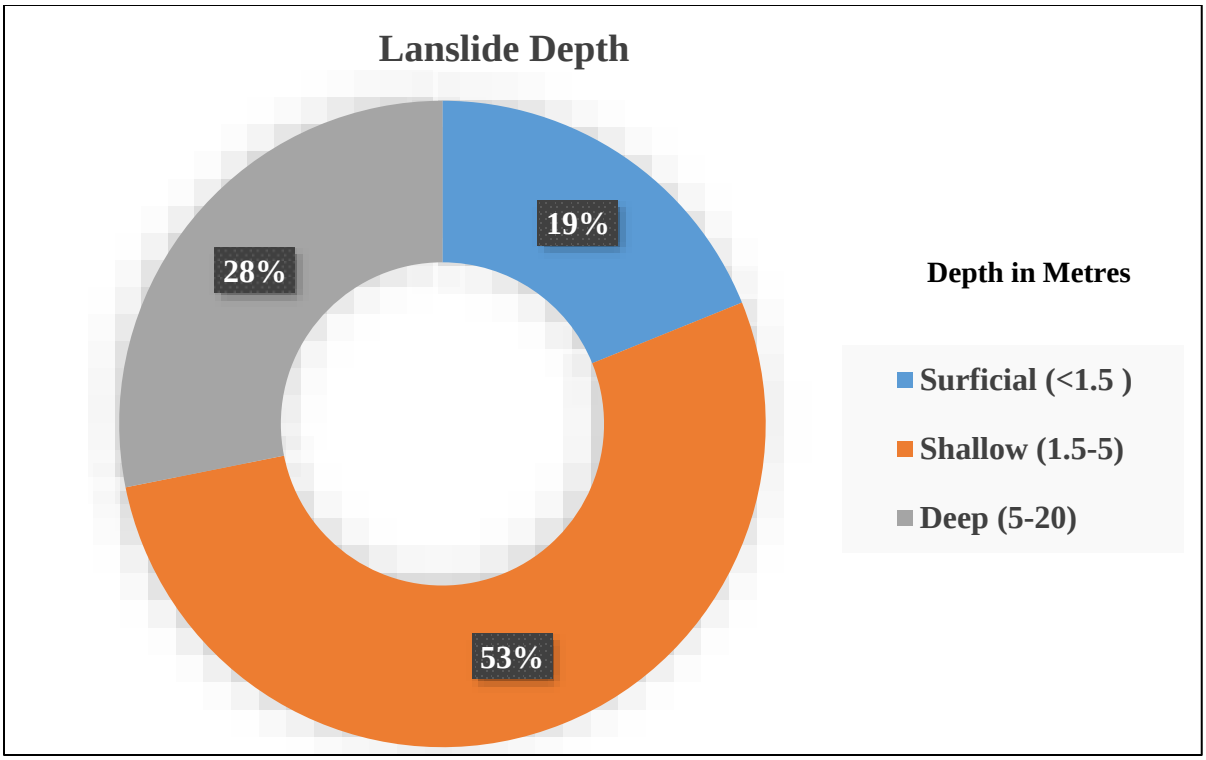

Figure 3; Depths of Landslides

The depth of landslides is shown in fig.3 which varies between 1 to 5 metres. The average depth is 3.32 meter, with a standard deviation of 1.51 meter. In the study area includes 28% deep landslides, 53% shallow and only 19% surficial landslides. The Hydrological condition of landslide at the time of survey is shown in (fig.6) 49% landslides occurred in dry and 42% in wet hydrological condition. In the study area only 3.9% landslides have Subsidence type of movement mostly the slide type of movement is high (table:1). The attribute data reveals that 81% landslides are still in active mode following with 12% dormant landslides which is quite alarming. Only 6% landslides are in suspended mode. In the study area only 18% landslide sites have the mitigation measures (Table:2) which means still 82% landslide location need the mitigation to reduce the risk.

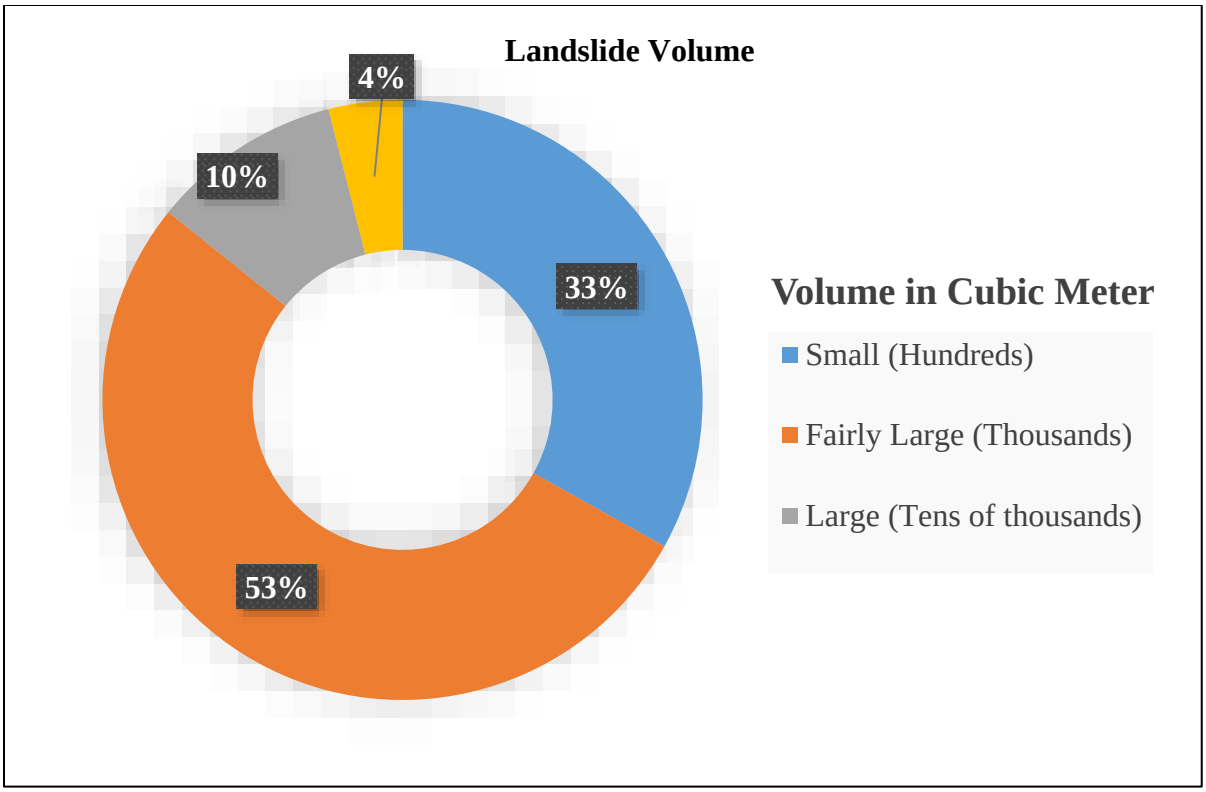

Figure 4; Volume of Landslides

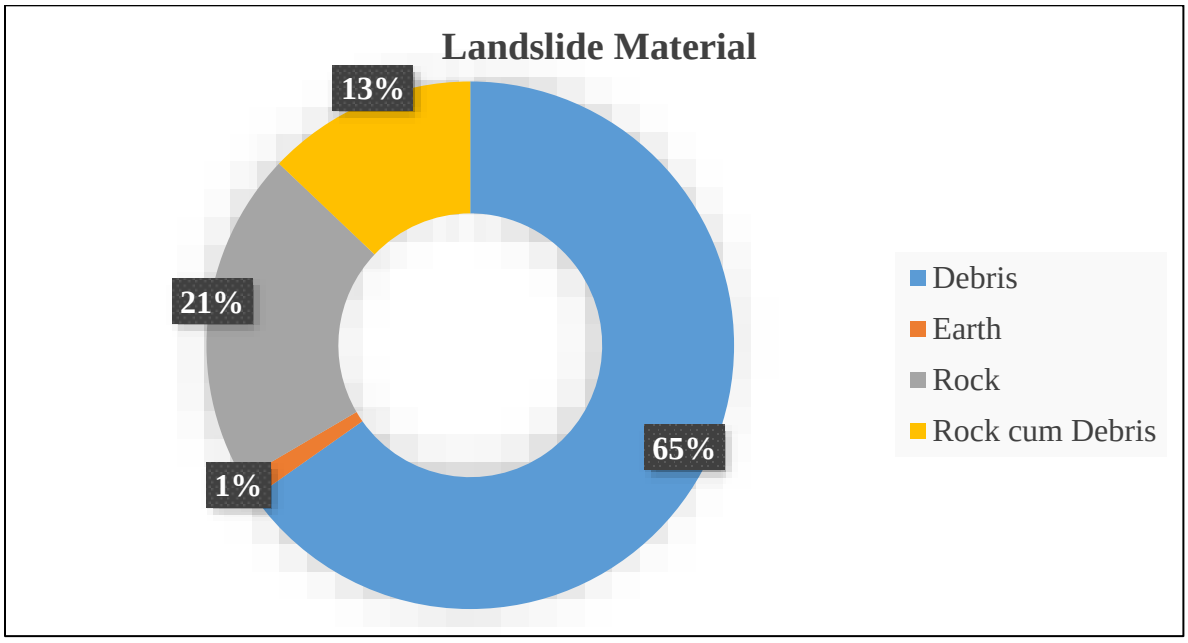

Figure 5; Landslide MaterialConclusion

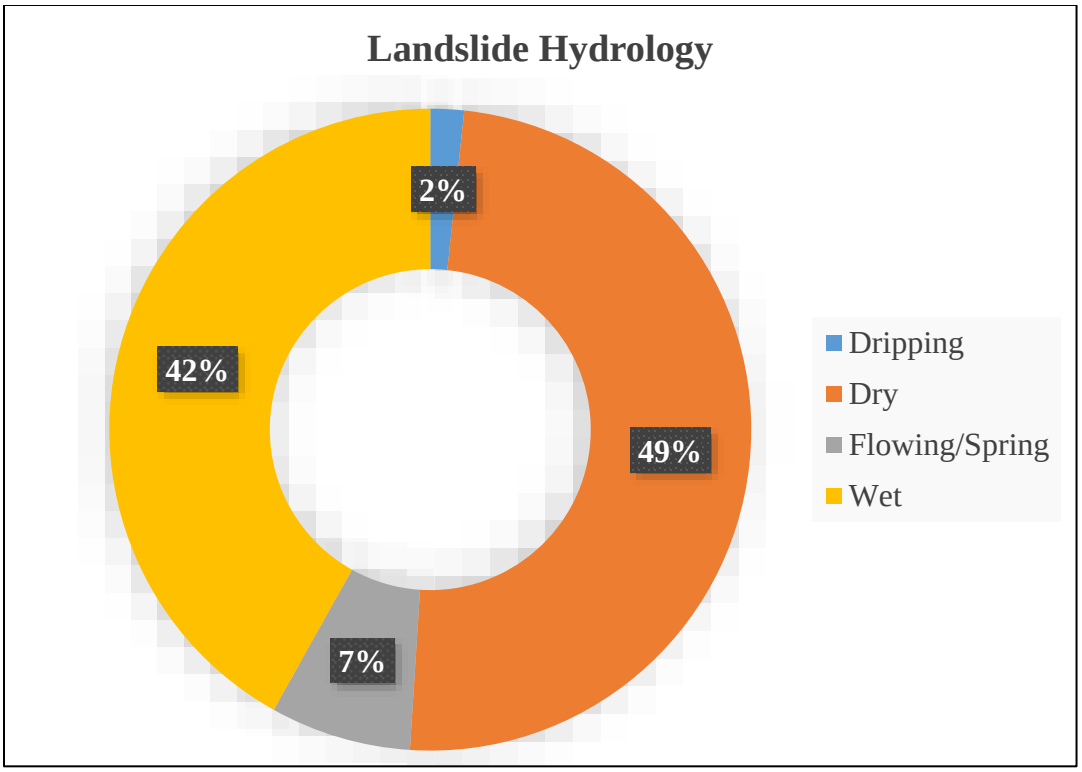

Figure 6; Landslide Hydrology

Table No 1; Landslide Movements

Movement type	No. of Landslides	Percentage
Complex	1	0.33
Composite	5	1.66
Creep	3	0.99
Fall	8	2.65
Flow	1	0.33
Slide	267	88.41
Subsidence	12	3.97
Topple	5	1.66
Total	**302**	**100.00**

Table No 2; Mode of Landslides

Mode of Landslide	Landslides	Percentage
Active	245	81.10
Dormant	37	12.30
Reactivated	1	0.30
Stabilised	1	0.30
Suspended	18	6.00
Total	**302**	100.00

Conclusion

It is clear from this study that the national highway stretch from Mandi to Manali has a large number of landslides. Landslide events are found in linear pattern along the national highway and the river Beas. In all types of landslides

debris slide dominate mostly, followed by the rock fall as this Himalayan region is made up with the sedimentary rocks. The sedimentation of alluvium material is also carried out by the Beas River. According to the volume of the landslides, 12 out of 302 landslides are in very large category of volume from which 6 occurred between Gulaba and Marhi near Rohtang pass as this area has no vegetation cover and it is also due to Unsupported slope cutting on this Leh-Manali highway stretch. Collectively the total 302 landslides occupy about 1.5 million square meter area and have displaced 8.3 million cubic meter of slop material in the study area. As Kullu and Manali are the main tourist attraction the large number of economic activities and ongoing development programme like road widening and other anthropogenic activities have made the area more vulnerable to landslides. The spatial pattern map and landslide characteristics data would be helpful for the decision making and for selecting the mitigation measures in the study area.

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