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Mitigation and Prevention of Landslide Hazard of Himachal Pradesh in the Lesser Himalaya

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Abstract

Landslides are destructive geological processes that have globally caused deaths and destruction to property worth billion dollars. Landslide occurrences are widespread and prolific in India covering more than 15 per cent of the total area. These are mostly concentrated in the Himalayan belt, parts of Meghalaya Plateau, Nilgiri Hills, Western and Eastern Ghats. The slope failure in the hilly terrain is due to geological processes and events. The frequency and magnitude of slope failure also increased due to anthropogenic activities such as road construction, deforestation and urban expansion. Keeping all these problems in mind research focuses on the Lesser Himalaya of Himachal Himalaya as it falls under very high risk zone in case of landslides and comprise of three objectives. They are: a) to analyse the spatial pattern of landslides in the Lesser Himalaya, b) to assess the causes of landslides vulnerability in the study region and c) to suggests some preventive measures to mitigate landslides. In this work an attempt has been made to collect data on landslides incidences and damage from the secondary sources like Geological Survey of India, Building Material and Technology Promotion council from Ministry of Urban Affairs.

The methodologies adopted for data analysis are simple tabulations, bar diagrams, statistical and mapping techniques to represent the Landslide vulnerability of the Lesser Himalaya. The analysis of the study reveals that there is increase in the number of landslides. The spatial pattern of landslide shows linear patterns, viz. along roads, rivers or lineaments/ faults. Besides, heavy rainfall, floods and earthquakes enhance the vulnerability condition. The landslides may be part and parcel of the Himalayan landscape, but they can be mitigated by some suitable measures. Few methods of landslide prevention in the study region have been suggested.

Keywords: vulnerability, prevention, mitigation

1. Introduction

Landslides are downward and outward movement of slope materials such as rock debris and earth materials under the influence of gravity, resulting due to natural causes, vibrations, overburden of rock materials, removal of lateral supports, change in the water content of rock or soil bodies, blocked drainage etc. The fragile nature of rock forming the mountains, along with climatic conditions and various anthropogenic activities has made the region vulnerable to the vagaries of nature. Besides earthquakes, landslides are the other geological hazards that are common and peculiar to the region. Landslides are simply defined as the mass movement of rock, debris or earth down a slope and they include a broad range of motions whereby falling, sliding and flowing under the influence of gravity dislodges earth material. They often take places in conjunction with earthquakes, heavy rainfall resulting into flash floods and cloud bursts. In the hilly terrain of India, landslide is a major and widespread natural disaster which occurs during the monsoon period, i.e., from July to September and after the snow fall, i.e., from January to March. The most common types of landslides are debris slide, rock slide, rock fall, slump, wedge failure and planer failure.

2. Study Area

The study region for the present research is the Lesser Himalaya of the Himachal Pradesh. It is located towards the middle part of the Himachal Pradesh having the Shiwaliks towards its south and the Greater Himalayas towards its north. It extends between 33°03′ North latitude to 30°41′ North latitude and 75°75′ East longitude to 79°03′ East longitude as shown in Figure 1. The study region comprises 68 tehsils which falls in 3 districts and part of 5 districts. Geologically the Himachal Himalaya, i.e., the Western sector of the Himalaya, consists of a complex sequence of massive Palaeozoic and Mesozoic rocks. The study region consists of mainly massive quartz intruded by basalts and other crystalline rocks of unfossiliferous sediments. The Lesser Himalaya of the Himachal Pradesh has a complex topography which is largely made up of hills, mountains and valleys. The region is drained by major river systems i.e., Ravi, Beas, Satluj. The soils of the Lesser Himalaya of the Himachal Pradesh are neutral to slightly alkaline and severely eroded with low to medium capacity to absorb nutrients. The study region is moderately forested part of the state and vegetation pattern varies from dry scrub at lower altitudes to alpine meadows at higher altitudes. There is a considerable variation in the distribution of rainfall and temperature due to varying aspects and altitudes. The Lesser Himalaya of the Himachal Pradesh is situated in the sub-tropical latitude, but owing to its altitude, or ographic features and snow covered peaks, the climate of the greater part of the study region resembles to that of mountainous and continental parts of the temperate latitude.

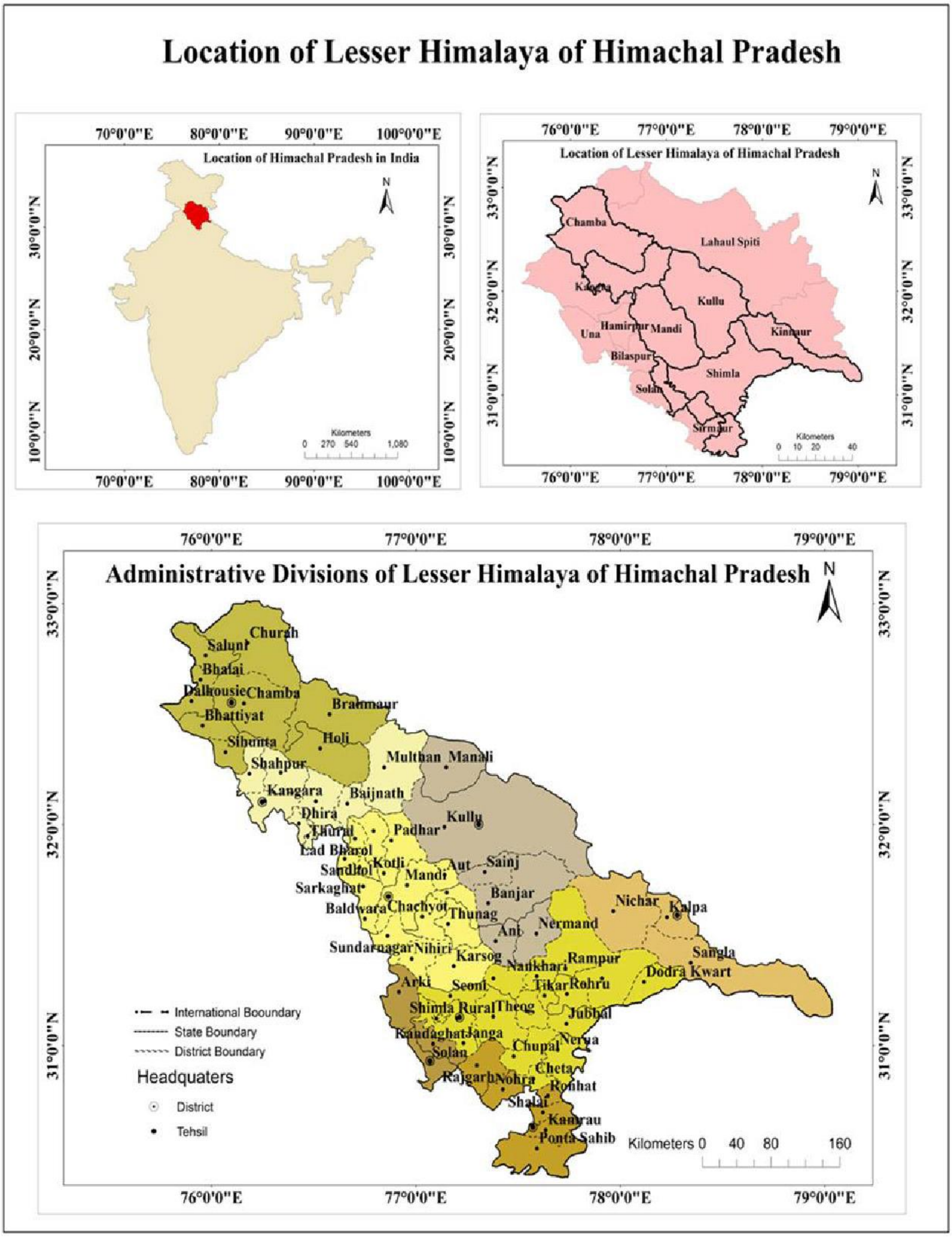

Figure 1.

The Lesser Himalaya of the Himachal Pradesh is the home of about 39, 96,093 persons with an average density of about 145 persons per square kilometer. Agriculture, forestry, horticulture and floriculture are the major economic activities among the local people. Small scale industry and tourism are the major economic activities of the immigrants. The area is under major cereal crops such as wheat rice, maize and barley. The average size of land holding is just little above one hectare due the increase in population over the years. The promotion of horticulture has been prompted due to suitability of the climate and higher returns. Floriculture has also emerged as a cash crop, yielding very high returns and a potential for export.

3. Nature of Problem

The Lesser Himalaya of Himachal Pradesh is one of the most dynamic hilly regions in the country and is located towards the western part of the Himalayas. Its forests, fruits, minerals, hydel power resources and health resorts hold the great promises of development. It has its own rich culture, physiography suited to almost all types of crops and fruits. The region is known as 'the apple belt' of India. Its vast potential for hydel power generation due to its locational advantage has attracted the attention of entire nation as a major resource awaiting exploitation.

The state has the highest heat flow and highest thermal gradient geothermal basin in India.

Pisciculture is widespread because of the numerous rivers and streams. Its physical diversity, its climate and peaceful environment can derive high economic value from the development of the tourism industry. Having all these unique resource potentialities, the region has been prone to a number of disasters since time immemorial as it is situated on the earth's most dynamic plate boundary. Landslide is the most important geological hazard and is a matter of concern as almost every year the study region experiences it in one part or the other. The study region falls under very high-risk zone of landslides as per estimates of Building Material and Technology Promotion Council of India. The incidents and magnitudes of landslides have been increasing not only due to biophysical vulnerability but also socioeconomic vulnerability. The vulnerability of the geologically young and unstable steep slopes has been increasing due to inappropriate activity such as deforestation, unplanned road cutting, and changes in land use pattern for agricultural development requiring large amount of water.

4. Objectives, Data Sources and Methodology

The following aspects related to landslides are proposed to be studied. They are: a) to analyze the spatial pattern of landslides in the Lesser Himalaya, b) to assess the causes of landslide vulnerability in the study region and c) to suggests some preventive measures to mitigate landslides. The study is based on both primary as well as secondary sources of data. The data such as geology, structure, slope, geomorphology, drainage, roads, landslides, earthquakes, flood and cloudbursts have been collected from concerned government departments, viz Geological Survey of India, Chandigarh; State Council of Scientific Technology and Environment, Shimla; Indian Meteorological Department, New Delhi; National Bureau of Soil Survey and Land Use Planning, New Delhi; and Public Works Department, Shimla. Primary data have been collected in sample location by interviewing local people and concerned government officials. All these data have been processed by using GIS software (ARCGIS).

5. Incidences of Landslides in the Lesser Himalaya of Himachal Pradesh

The landslide inventory of Himachal Pradesh enumerates over 350 landslide incidences in the state as per estimates of inventory of Landslides published by Geological Survey of India (2005). Out of these, around 285 have been recorded in the Lesser Himalaya of the Himachal Pradesh. Majority of the landslides have been recorded during the preparation of landslide zonation maps in Satluj, Ravi and Beas river valleys in the Kullu, Mandi, Kinnaur, Chamba and Kangra districts in 2005. Many of these slides have been investigated during the geo-technical investigations of river valley projects and for feasibility study of the road alignment and rural and urban settlements. The present inventory indicates that the road runs along Ravi River between Gehra and Brahmaur in the Chamba district is highly affected by landslides. The road alignment in the stretch passes through jointed rock mass belonging to the Chamba formation represented by interstratified sequence of slates, phyllite and subordinate schist; Manjir formation comprising pebbly siltstone, slate and bands of limestone; and Kataria Gali formation composed of interstratified sequence of slates, phyllites, siltstone and beds of thinly bedded limestone. The Hindustan Tibet road alignment between Jeori and Khab passing through slope wash, debris, jointed gneiss and compact granites of Rakcham granite formation is another sector which is widely affected by landslides. This tract falls in the Kinnaur district along the Satluj Valley. Shimla is frequently experiencing landslides with slips and subsidence commonly occurring with overburden materials and adversely affecting roads and unsoundly founded constructions. Soil creeps and landslides have also occurred in Dalhousie town, where closely jointed slates are covered by a thick overburden consisting of fragments of the slate embedded clayey matrix. The materials are loose and incompetent.

6. Spatial Pattern

There are total 285 incidences of landslides recorded in the Lesser Himalaya of the Himachal Pradesh. The pattern of landslide occurrences is not uniform all over the Lesser Himalaya of the Himachal Pradesh. Out of the total 285 landslides recorded in the study region, it is seen that the Chamba district outnumbers all other districts with 107 landslides. The districts in terms of the occurrences of landslides after Chamba is Kangra with 67 landslides followed by Kinnaur with 43 landslides, Shimla with 39 landslides, Kullu with 20 landslides, Mandi with 8 landslides. The Sirmaur district has just one landslide record where Solan district has not recorded single incident of landslide. This was a district wise distribution but tehsil wise pattern even gives a more precise spatial pattern. In the Chamba district the maximum landslides have been recorded in the Brahmaur tehsil followed by Chamba, Holi, Sihunta and Churah tehsils respectively. In the Kullu district the maximum landslides has been experienced by the Nermand tehsil followed by the Ani tehsil. In the Kangra district the maximum landslides recorded in the Dharamshala tehsil followed by the Palampur, Shahpur, Baijnath Kangra and Multan tehsils respectively. In the Shimla district, the maximum incidents have been recorded from the Rampur tehsil followed by Kumharsain and Shimla (R) tehsils. In case of the Mandi district the maximum landslides recorded in the Karsog tehsil followed by the Padhar, Jogindernagar and Lal-Badrol Tehsils, respectively. In the Kinnaur district the maximum incident recorded in the Nichar tehsil followed by the Sangla and Kalpa tehsils respectively. The Sirmaur district has just one landslide in its share and that too in Kamrau tehsil. If we see the tehsils recording higher occurrences of the landslides are Brahmaur (78) tehsil followed by the Rampur (30) tehsil, Nichar (25) tehsil, Dharamshala (23) tehsil and Palampur (20) tehsil.

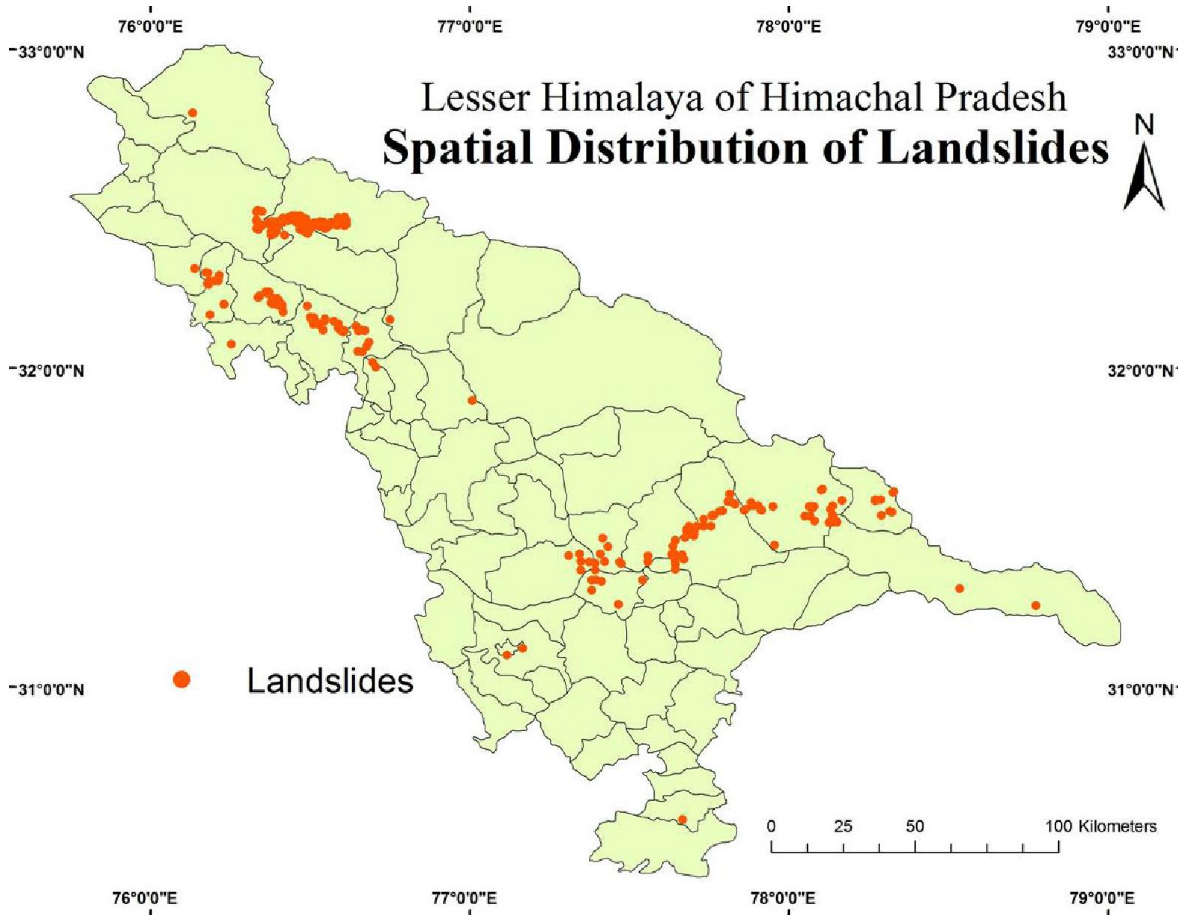

Figure 2.

7. Types of Landslides

The landslides of the study region can be divided into different categories — rockslide, debris slide, wedge failure, planar failure, rock fall and slumping (Table 1). The Figure 2 shows spatial distribution of all these types of landslides which are described as follows.

Rockslide is a type of rock failure in which part of the plane of failure passes through intact rock and where material collapses en masse, not in individual blocks. It is thought that pore-water pressure in the joint system play a critical role in inducing rockslide. However, but slides can also occur in homogenous un jointed rocks. Rockslide is not most significant of all types of slides where in large blocks slide down the hill slope. Rock slides are very catastrophic phenomena in mountain region where high relief permits acceleration of rock debris to a velocity as great as those of rock falls and rock avalanches. Rock slides involve rapid movement of the material down slope. The spatial pattern of the rock slide in the Lesser Himalaya reveals a scattered pattern with clustering at few places. There are about 93 rock slides out of the total 285 landslides which constitute 33 per cent to total. Out of the total rock slides the maximum incidents have been recorded in the Rampur tehsil of Shimla district followed by the Nichar (Kinnaur), Nermand (Kullu) and Brahmaur (Chamba) tehsils respectively. The wedge failure is the process of rock collapse generated by the intersection of two or three high angle joints on a free face and where fractures dip down the face of the cliff. There are about 70 wedge failure incidents reported in the study region which constitute 25 percent of the total landslides. The Figure 3 shows that wedge failure are concentrated in the Chamba and Kangra districts of the Lesser Himalaya. The tehsils facing wedge failure problem are Braumaur followed by Holi, Chamba tehsils Dharamshala, Palampur, Shahpur and Baijnath, Jogindernagar respectively. The planer failure is a large failure on one or more plane surface and 10 events of it has been recorded in the study region which constitute 3 percent of total landslides. As compared to the wedge failure the planar failure is recorded from the various parts of the Lesser Himalaya of the Himachal Pradesh. The districts like Chamba, Shimla, Kullu and Kangra experienced the planar failure. The tehsils facing planar failure are Brahmaur, Rampur, Nermand, Kangra, Baijnath, Palampur, Dharamshala. Debris slide is more extensive and occurs on the large scale than slump but there is little amount of water. Debris slide is promoted because of two basic factors. One is saturation of rocks due to water and other is sudden down slope movement of unconsolidated mantle rock. The materials involved in debris slide are a mixture of soils and rock fragment. The debris collects at the foothill or at the valleys. There are about 81 debris slide out of the total 285 landslides which constitutes 28 percent. Out of the total debris slides the maximum incidents have been recorded in Dharamshala followed by Palampur, Nichar, Kalpa, Kumharsain, Rampur respectively.

Rock fall is facilitated by granular and block disintegration of rocks under the process of mechanical weathering and limited action of oxidation in sandstones. The frequency of rock falls depends on certain environmental conditions such as aridity/humidity factors, lithological and structural characteristics of rocks, nature of slopes and vegetation etc. It is a process by which small blocks of rock become detached from a cliff foot. Loose blocks can only be produced where there are suitable joint patterns in the rock, thereby enabling differential expansion and contraction and freeze and thaw mechanism to come into play. Out of the total 285 landslides, 26 are rock falls (9 percent). The maximum number rock falls is recorded in the Brahmaur and Palampur tehsils.

Table 1. Types of landslides (compiled by Author based on Geological Survey of India)

Type of Landslides	Numbers	Percent to total
Rock Slide	93	32.63
Debris Slide	81	28.42
Rock Fall	26	9.12
Wedge Failure	70	24.56
Planar Failure	10	3.51
Slump	05	1.75
Total	285	100.00

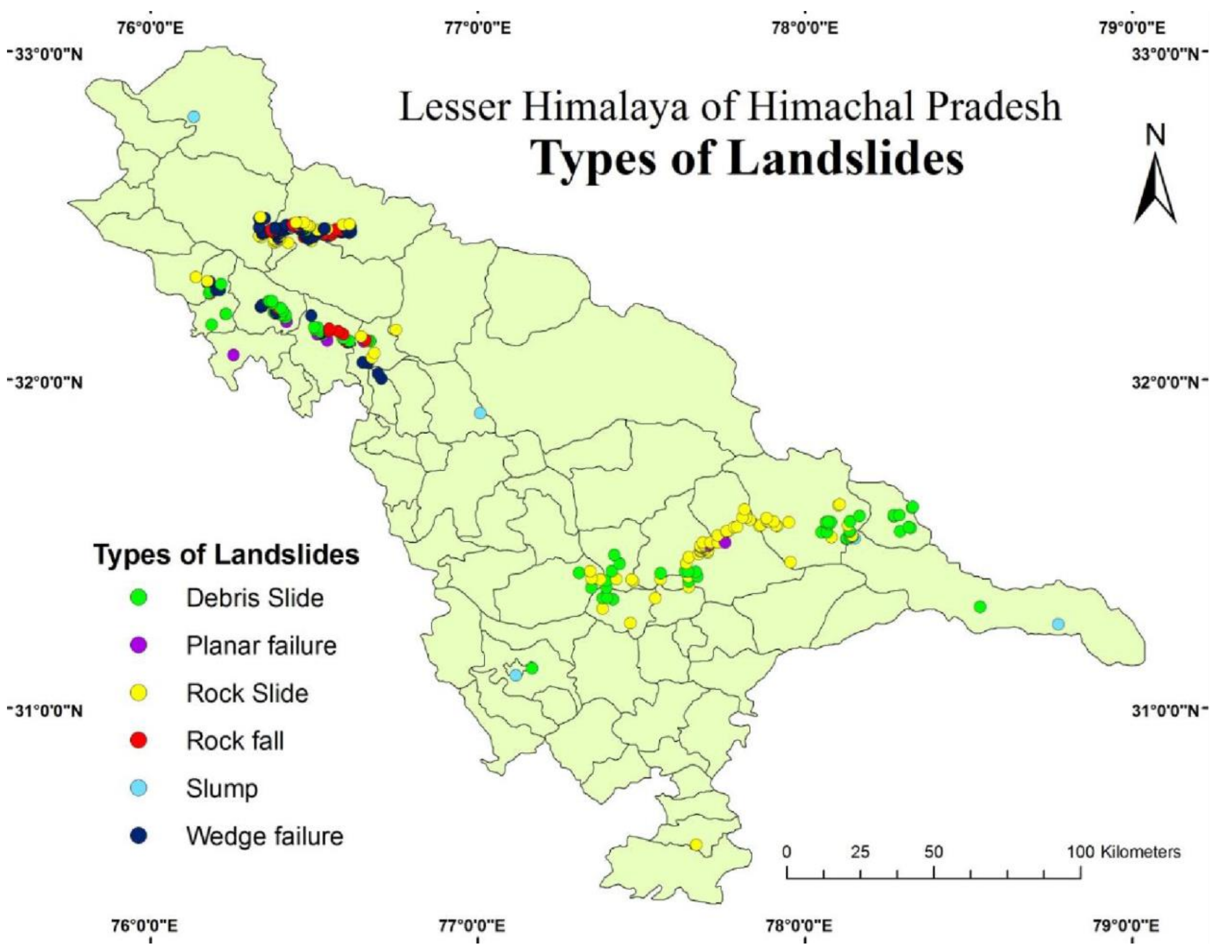

Figure 3. Types of landslides (compiled by Authors based on Geological Survey of India)

Slumping involves intermittent sliding of rock fragments; rock blocks or soil down slope along a curved plane caused by rotational movement and displaced blocks cover very short distance. Slump is promoted by undercutting of slope base by streams and by human activities. It is mass of surface rocks or superficial materials that becomes detached from a hill side along a slip plane and moves down slope often as a rotational slip. Out of the total 285 landslides, there are only 5 slumps (2 percent). The rock slump is isolated in nature. They are recorded from the Shimla rural, Padhar, Churah and Sangla.

8. Causes of Landslides

The Lesser Himalaya of the Himachal Pradesh is a mountainous region having rugged topography and deep and narrow valleys and steep slopes which make it very prone to different types of slope failure namely land sliding, slumping or creeping, rock fall, shooting stones, etc. This problem has been compounded by the increasing anthropogenic activities. The main cause of slope failure or landslide is steep and fragile slopes, loose soil, fissured or fractured rock strata, some tectonic activity, heavy rainfall, toe erosion by running water and human intervention with the natural settings like various unplanned construction activity, deforestation, faulty land use practices, use of explosives in construction, practicing unscientific mining, quarrying, tunneling methods, unscientific dumping on the valleys etc.

It has been also observed that landslides are not dependent on one factor but controlled by a number of factors such as structure, lithology, slope, drainage pattern, rainfall as shown in the Figure 4 and Figure 5. The superimposed map of all these when seen in relation to the landslides, it is evident that the concentration of landslides is seen in linear pattern in the three locations in the study region. The first linear pattern of landslides is observed towards the northwestern part of the study region in the Chamba district. The landslides here occurred on the very steep slopes. The occurrence of landslides along the river Ravi is considered another important factor. The second linear pattern is also found towards the northwestern part of the study region in the district of Kangra.

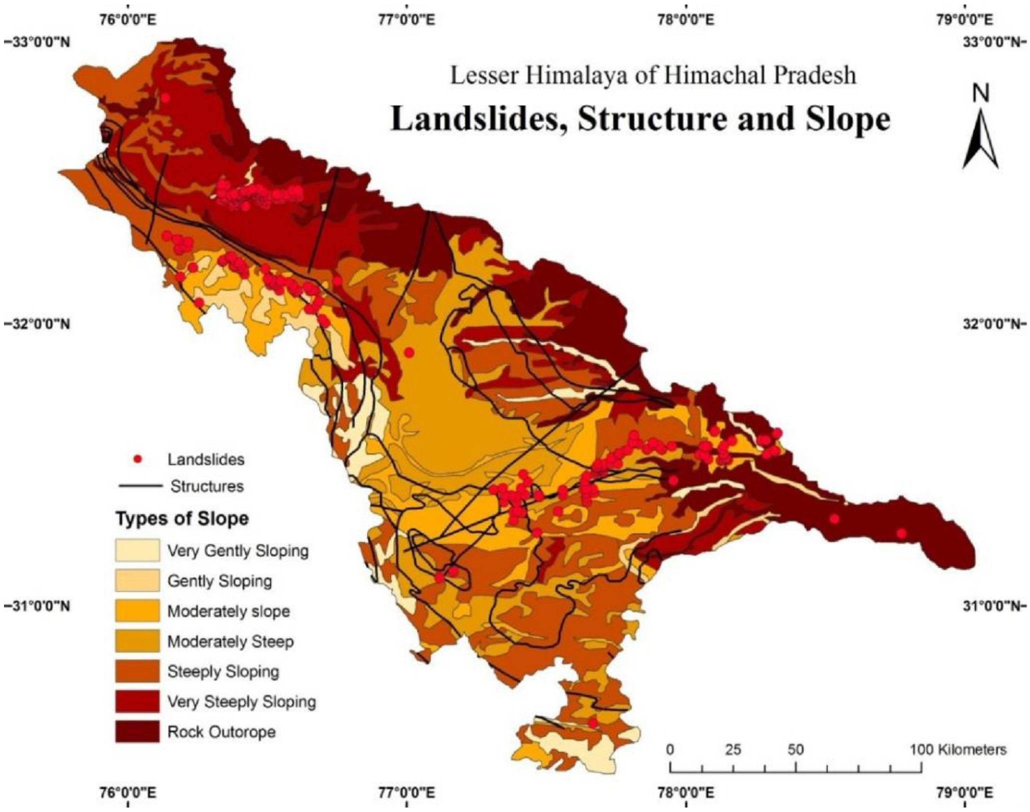

Figure 4. Landslides, structure and slope (compiled by Authors based on Geological Survey of India)

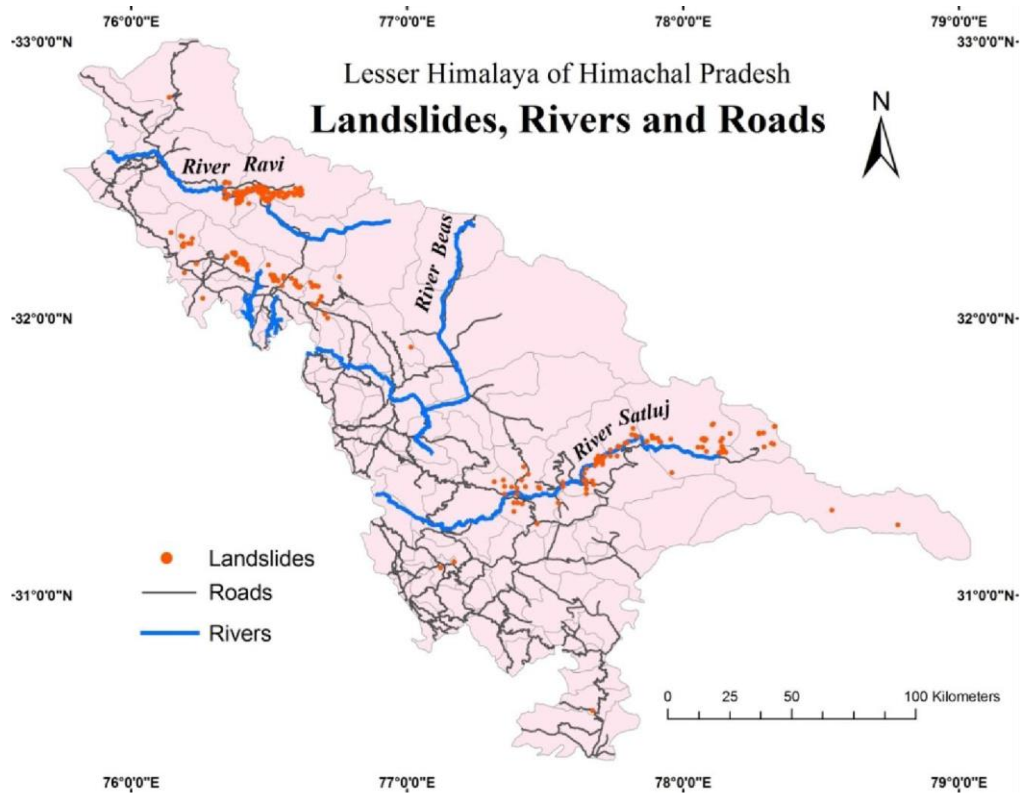

Figure 5. Landslides, rivers and roads (compiled by Authors based on Geological Survey of India, Census Atlas)

The moderately steep slopes along National Highway 20 which is parallel to Dharang thurst and on Dhauladhar range ridge line. Cloud burst leading to high rainfall is the main cause of landslides here. The third linear pattern is found towards the southeast part of the study region. The landslides in this patch occurred on the moderate slopes but are seen all along the course of the river Satluj. The disastrous effect of these slides is observed mainly along National Highway 20, National Highway 21 and National Highway 22 (Now NH 5), old Hindustan-Tibet Road and other link roads connecting the villages of the district. The important landslides of the district are *Powari landslide, Luggar Bhatti and Nathpa landslide* etc. The main roads leading to various parts in the study region are like flashpoints which if triggered by natural events block the connectivity. Such susceptibility is very high for other internal roads of the districts. In Himachal Pradesh, roads are constructed where the rocks could be broken easily, viz. along the major rivers or along major faults/ structure. Major rivers are prone to flash floods particularly in rainy season which increase the vulnerability of landslide. The fault lines are also prone to landslides. Along Dharang thurst, earthquake beyond 5.0 and up to 7.0 magnitude on the Richter Scale have been occurred in 1827, 1905, 1945, 1947, 1986 and 1978. If this type of earthquake with magnitude beyond 7.0 on the Richter scale occurs today, it would increase the vulnerability of landslide. Landslide is the major hazard in these regions which is in most cases initiated by anthropogenic activities and intensified by natural factors particularly during rainy season. The various causes mentioned by the Geological Survey of India includes building pore water pressure and loss of shear strength of rock mass due to over saturation; excessive erosion along rivers leading to the steepening of the hill slope; removal of toe support; intersection of joints.

9. Prevention and Mitigation Strategies

The most important triggering mechanism for mass movements is the water infiltrating into the over burden during heavy rains and consequent increase in pore pressure within the over burden. When this happens in steep slopes the safety factor of the slope material gets considerably reduced causing it to move down. The natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels both micro and macro in vulnerable slopes. The universal use of contour bounding for all types of terrain without consideration of the slope, overburden thickness and texture or drainage set-up needs to be controlled especially in the plateau edge regions. It is time to think about alternative and innovations, which are suitable for the terrain, to be set up. It need not be over-emphasized the governmental agencies have a lot to contribute in this field. Leaving aside the 'critical zones' with settlements could be avoided altogether and which could be preferably used for permanent vegetation, the 'highly unstable zones' generally lie in the upper regions, which are occupied by highly degraded vegetation. These areas warrant immediate afforestation measures with suitable plant species. The afforestation programme should be properly planned so the little slope modification is done in the process. Bounding of any sort using boulders etc. have to be avoided. The selection of suitable plant species should be such that can withstand the existing stress conditions in this terrain.

The landslide mitigation and control measures depend upon the detailed investigations, including identifying causative factors. In general, the chief mitigation measures to be adopted for such areas are drainage correction, proper land use measures, reforestation for the areas occupied by degraded vegetation and creation of awareness among local population. Some of the common landslide flow control measures in the Himalaya are given in following paragraphs;

1) Proper drainage should be provided to dispose the household water particularly in slide prone areas.

2) Cultivation of paddy should be stopped in slide prone areas and along the hill top because tilling and irrigation increase the infiltration rate.

3) Though it is difficult to alter the existing century old land use, particularly agricultural practices in the rural landscape of Himalayan slopes but in some cases where occurrence of slides are common, and slopes are vulnerable, appropriate land use alteration is required to reduce the mass movement processes.

4) Most of the villages along the Himalayan

slopes are located on old landslide mass, old glacial and periglacial deposits or on hill slope scree which provides good land for cultivation.

The increased population pressure and construction of roads without necessary geological and environmental assessment in such areas make the slopes more vulnerable for landslides. Compulsion of people to continue to live in such known landslide prone areas has their limitations. Either there is no other place available to live or they have economic limitations to control or minimize the landslide and mass movement activity.

5) The control of landslide demands a detailed knowledge of certain parameters related with landslide like, property of the sliding surface, sliding body underlying and surrounding geological formations and hydrological conditions. The optimum control measures depend on the comprehensive information available for a particular slide. There are a number of techniques adopted to control the landslide singly or in combination depending on the nature of slide, terrain conditions (slope etc.) climate (rainfall/snow) and geological conditions. For the surficial and deep sheeted landslide following techniques are most effective.

a) Vegetative Turfing: It is the most effective and most important corrective measures particularly for the fresh exposed surface produced by road cutting and mining. Planting fast growing grasses and bushes in the landslide area is the first step in this direction. Planting fast growing grasses, shrubs, trees and bamboos followed by putting of jute net or vegetated stone pitching upon the freshly-turfed area would ensure rapid and undisturbed growth of vegetation (HOWELL, 2001).

b) Bio-Engineering: It is the very economical means to control landslide and soil erosion using live plants and plant parts. Through plantation of grasses, shrubs, tree and bamboo, lining of grasses and shrub cuttings, applying jut net or vegetated stone pitching.

c) Spraying: Certain spray is used to cut down the surficial erosion and to improve the moisture condition of soil to facilitate the vegetal Turfing. Such a spray treatment known as asphalt mulch treatment is most effective for the Indian conditions. In this treatment asphalt emulsion of specific grade is spread by a suitable sprayer on the effective slopes in optimum quantity just to retain the growth of seed and plants. After sometime when vegetal cover develops the asphaltic film gradually disintegrates.

d) Slope Netting: Netting of slopes stop the down ward movement of material reduces the impact of kinetic energy of rain drops thus surface water flows. Netting is usually done by coir or jute nets and some time by wire nets or synthetic net. Before netting fertilizer is spread on the slopes for fast growth of seeds and seedlings of grasses, bushes or suitable plants.

e) Check Dams: It controls surface runoff and improve the moisture condition for the growth of vegetation in slide affected areas. Generally, the stakes of bamboo or stakes of regenerating branches of local trees are used. In the clay rich areas grass and bushes are used in order to reduce the over burden caused by the growth of higher plants. In some cases, check dams are also constructed by rocks available in slide area and the benches are duly planted by some fast-growing species.

f) Channelizing the surface and sub-surface runoff: In order to reduce the surface, run off and percolation surface drainage is constructed in unstable high gradient hill slopes. The small staircases and artificial rapids are made to reduce the velocity of water. To reduce the pore water pressure the subsurface, percolated or perched water should be drained out through constructing the tunnels across the deep sheet sliding mass and perforated pipe is shallow sliding mass. In slide areas this method reduces the hydrostatic and hydrodynamic pressure of ground water.

g) Retaining walls and Buttresses: In areas of restricted space and those close to other structure retaining walls and buttresses are used. This is particularly use full to stop the movement of freshly cut slopes during road and building construction sites. Low walls are used to fasten the toe of existing slide. This method also reduces the artificially generated dynamic forces like blasting, vehicle vibrations.

h) Treatment of Shape of Slope: The reduction of load of rock and soil at the head of the slide through removing the material and changing the geometry of the hill slope by trimming of slide mass.

i) Grouting: Filling of fissures and cracks or blanketing the landslide by Portland cement in order to reduce or eliminate the chemical and physical processes that increase the volume of slide mass.

j) Piles: The timber, concrete or any type of piles are installed in the sliding mass below the slip surface in order to transfer the upper load to lower substratum. This method is much effective in the areas where a compact or hard strata lies below the sliding mass.

k) Anchoring: it is done in specific case to control the slide, where 7.5 to 15 cm diameter hole is drilled to the depth beyond the possible failure plane. The hole is grouted by cement and drilled again, and water test is carried out, thereafter the pre-treated high tension steel wires along with other anchor assembly is lowered down in the bore hole and made to watertight with pure cement. The number and networking depend on area to be stabilized.

10. Conclusions

The Lesser Himalaya of the Himachal Pradesh is a mountainous region having rugged topography and deep and narrow valleys and steep slopes which make it very prone to different types of slope failure namely land sliding, slumping or creeping, rock fall, shooting stones, etc. This problem has been compounded by the increasing anthropogenic activities. The main cause of slope failure or landslide is steep and fragile slopes, loose soil, fissured or fractured rock strata, some tectonic activity, heavy rainfall, toe erosion by running water and human intervention with the natural settings like various unplanned construction activity, deforestation, faulty land use practices, use of explosives in construction, practicing unscientific mining, quarrying, tunneling methods, unscientific dumping on the valleys etc. The incidences of landslides are regular phenomena in the one or other part of the Lesser Himalaya of Himachal Pradesh. Of all types of landslides, rock slides dominate mostly, followed by debris slides, rock falls and slumps respectively. Landslides are found in three linear pattern — along the river Ravi and Satluj and along Dhauladhar ridge line. The vulnerability of the geologically young and unstable steep slopes is due to the combined effect of the coexistence of geological structures, rivers (having high floods in rainy season), unplanned roads, developmental activities etc. To prevent landslide, it is necessary to prepare zoning maps of landslides and rock fall prone areas through detail geological and geotechnical studies. The pre-existing geophysical processes should be understood before taking any measure to prevent landslides. The landslide prone areas should be avoided while locating new settlements or building, and those which are already occupied, should either be resettled, or protective measures be adopted. The extensive road networks are imperative need, but proper planning is essential to avoid extensive personal and property damages. Often roads have been constructed without regard to the other factors of safety and leads to tragic accidents and frequent road blockades. There is necessity to strike a balance between development and good environmental planning which gives paramount importance to human safety.

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