

LANDSLIDE RISK MITIGATION METHODS ALONG THE TRANSPORT CORRIDOR: A CASE STUDY OF KULLU-ROHTANG PASS

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ABSTRACT

Landslide can be defined as the complex natural gravitational mass movement of rocks, debris or earth phenomenon that occurs in conjunction with other natural disasters. It has been identified as the most frequently occurring geo-environmental hazard between Kullu-Rohtang Pass region. The spatial and temporal distribution of landslide in the study region shows linear pattern viz. along roads, rivers and lineaments or faults. Heavy intensity of rainfall during monsoon season and occurrence of earthquakes enhance the vulnerable conditions of the region. Recently, it has been noticed that the area faced a major land cover change due to anthropogenic activities like slope cutting, construction of National Highway (NH-21), tunnel construction and thus probability of the occurrence of landslide has increased. This study is based on primary and secondary data. Having this background, the main objective of this study has been framed to the management of landslide hazards risk emphasising on the integrated landslide risk mitigation strategy and corridor management of the study area. The finding of the present study reveals that it is neither possible to stop the landslides nor to completely eliminate their damages but it is possible to minimize the impact through several structural and non-structural mitigation methods.

Keywords: Anthropogenic activities, Geo-environmental hazards, Landslide, Mitigation strategy, Risk.

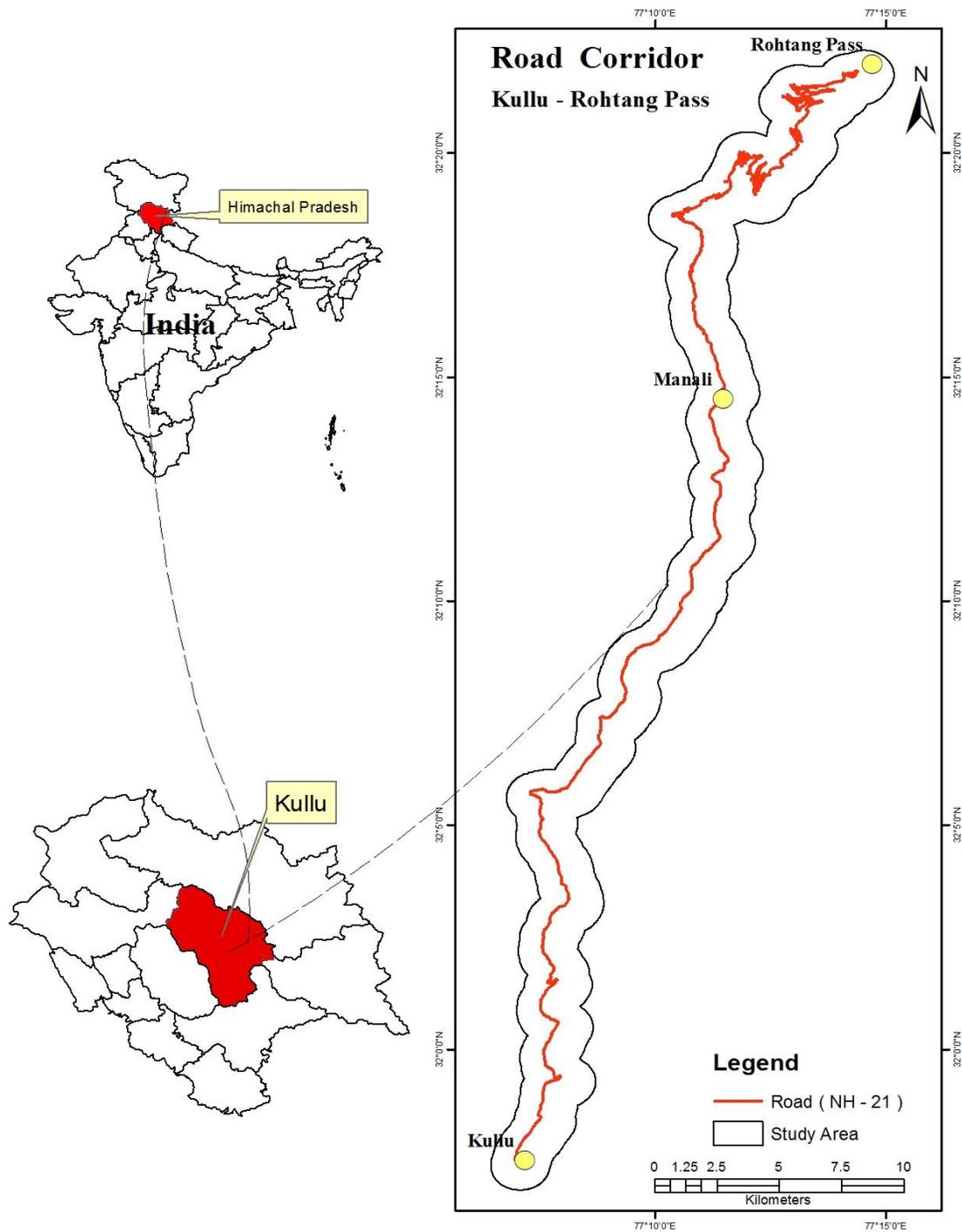
1. INTRODUCTION

Indian mountain regions are one of the most landslide prone regions of the world. Number of people affected by landslides is relatively lesser than those affected by other natural calamities such as earthquakes, floods, tsunami, etc. However, the damages from landslides are more permanent in nature compared to that of other disasters where normalcy is restored after some time. In India, 15 per cent of land area i.e. around 0.49 million km² and 22 states including the

parts of Union Territory of Pudducherry and Andaman and Nicobar Islands are affected by landslide hazard National Disaster Management Guideliness (NDMG, 2009). The alarming rate and frequency of landslide events increase during the monsoon period. In 2005, more than 500 human lives were lost due to this hazard (NDMG, 2009). Landslide hazard is the product of combined interaction between geographical and anthropogenic processes (Smith, 1992). The anthropogenic activities include changes in socio-economic activities as well as technological activities such as transport, industry, agriculture, mining, forestry and impacts of urbanization and tourism (Singh, 1991). In mountain areas such as Kullu to Rohtang Pass, the operation of several potentially hazardous geo-physical process necessitates the use of multiple hazards approach to the problem (Singh and Rowbotham, 1995). In the case of mountainous terrain, landslide hazard prone area has been traditionally avoided and are used for agricultural activities (Gurung, 1989). The Beas river catchment area from Kullu to Rohtang Pass is highly vulnerable to landslide hazards and is frequently triggered by the rainfall in monsoon season. Slope failure is also a major cause for landslide disasters in the study area. The diversity in slope components, degradation processes, micro-climatic conditions, soil texture, physical and chemical properties and unplanned growth of settlements have led to recurring landslide events in Kullu to Rohtang Pass. In order to reduce the enormous potential effect of landslide and consequential loss, the risk should be analysed in order to prepare an appropriate strategy or guidelines at district level as well as national level. Bottom to top level approach would be helpful in the proper implementation and functioning of structural and non-structural mitigation measures for landslide risk and management with the help of mass awareness generation programmes.

2. STUDY AREA

The study area between Kullu-Rohtang Pass is located in Kullu valley, Himachal Pradesh, India. Geographically, this area lies between the latitude $32^{\circ} 0' 0''$ N to $32^{\circ} 20' 0''$ N and longitude $77^{\circ} 5' 0''$ E to $77^{\circ} 15' 0''$ E along the catchment area of fast flowing Beas river (Figure 1). The study area is situated in the transitional zone between lesser and greater Himalayan Mountain ranges in the central part of Himachal Pradesh. Transport road corridors get frequent landslides occurrence especially during monsoon season. It has a rugged topography with moderate to high altitude from 1,279 m to 3,979 m from Mean Sea Level (MSL).



Source: Prepared by Author

Figure 1: Study Area Between Kullu to Rohtang Pass

3. DATABASE AND METHODOLOGY

The study is based on primary and secondary database. The primary information has been collected with the help of questionnaire and GPS. A semi-structured questionnaire has been used for this purpose. The selection of respondents was done through stratified random sampling method. The study area is divided into eight villages (4 between Manali-Rohtang Passs and 4 between Kullu –Manali) along the road corridor. About 25 respondents from each village were selected from all socio-economic backgrounds. The questionnaire included questions related to people perception about techniques and practices to mitigate and control the landslide risk. The secondary information has been collected from different reports, magazines, research papers and articles.

4. RESULTS AND DISCUSSION

The task of landslide hazard mitigation has to be a coordinated effort among the local authorities, state government, central government and other stakeholders concerning the landslide prone area. A number of factors such as the growth of urban centre, rural settlements and other infrastructural developmental activities increase effectiveness of landslide hazard response and landslide vulnerability (Mileti, 1994). The problems of landslide incidents in Kullu to Rohtang Pass area can be effectively controlled, however, it requires proper management and planning with sufficient financial resources and following structural and non-structural landslide mitigation methods.

4.1 Structural Mitigation Methods

4.1.1 Stability of Slope

The stability of slope can be substantially increased by its enlargement at the toe of the landslide and reducing the load of soil at the crown. Construction of man made hillside benching or terraces can be effective in reducing the impact of landslide hazard (Figure 2). Such method is used when the slopes are especially steep and the toe of the slide has been altered. Hillside benching prevent the build-up of slope long stress and they should be designed for easy maintenance.



Figure 2: Construction of Stability of Slope on National Highway-21

Road construction and growth of unplanned settlements along the steep slopes near the upper the Beas basin area, Palchan and Kothi village are the main causes of slope instability in the study area. So, the preventive steps should be taken by government to control these activities and prepare a policy for slope based construction of settlements.

4.1.2 Drainage Techniques on Slopes

Drainage system is one of the important preventive measures to mitigate the slope instability in many parts of the Kullu-Rohtang Pass. The lack of proper drainage system will continuously affect the hills slopes and increase vulnerability of landslide events and make it even more prone to landslides (Figure 3). Major landslide event at near Dawara village in Kullu district and Bhang village in Manali area caused by drainage system.



Figure 3: Effect of Proper Drainage System in Bhang Village, Manali

The most important triggering mechanism for mass movements is the water infiltration into the overburden during heavy rains and consequent increase in pore pressure within the overburden. Hence, 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 course correction and promotion of water harvesting measures. This involves maintenance of natural drainage channels both micro and macro in vulnerable slopes. If the drainage system is scientifically planned and designed between Kullu-Rohtang Pass than future occurrence of landslides events will decrease (Figure 4).



Figure 4: Planned Drainage System Near Palchan Village, Manali

4.1.3 Retaining Wall

Construction of retaining wall along the road corridor and hilly slopes especially along the toe of the hill to support the rock mass. The construction of retaining wall depends on techno-economic factors and availability of the material.

Provision of sufficient weep holes with proper filtering is more essential for retaining structures (Figure 5). The height of the retaining wall depends on the calculated risk factor of a particular landslide spot. Construction of retaining wall in the study area is strongly recommended for the Nehru Kund site to get the terrain stability as well as avoid further slope failure conditions.



Figure 5: Retaining Wall Near Nehru Kund, Manali

4.1.4 Rock Bolts

Rock bolts is used to prevent movement of rock slopes or stabilize rock slide. It is one of the suitable methods of rock mass support especially where rock is cut vertically. The use of this method has become popular in certain situations in last few years. They work best in rocks that are joined with planes of discontinuity inclined downslope. They are usually composed of steel rods that are inserted at angles to the planes of weakness. A rock bolt reduces the disturbing force acting down the plane of discontinuity and increases the relationship between the base of the block and the plane.

4.1.5 Wire Mesh Crates

It is a systematic arrangement of uniformly cut rock blocks within the wire mesh. It requires proper network of wires along the toe of the hill and it reduce the vulnerability of landslide incidences. The Public Works Department (PWD), in Kullu district has already adopted this measure.

4.1.6 Contoured Benches and Terraces

This method is proposed in the erosion prone areas along with planting of tress and grasses. Vulnerable sites are identified in the study area and are suggested for construction of contour benches and terraces to control the erosion in the landslide hazard prone areas.

4.1.7 Cement Grouting

This method is used for making of inclined drill holes in to hill mass and it is fillet by cement with pressure through pump. In this method cements spread entirely in gaps between the rocks and shears plane resulting in completely blocking of the weak plane, hence reducing the vulenerability of landslides.

4.2 Non-Structural Mitigation Methods

4.2.1 Plantation

Slope stability movements are generally disturbed by deforestation, overgrazing activities and removal of vegetation cover from the land surface. The afforestation on the slopes sides is an important corrective measure to mitigate the landslides (Figure 6). Trees or shrubs are planted from time to time on the slope as they create a dense network of roots in the soil and a canopy over the surface. Trees and shrubs planting methods can be applied on 35⁰-45⁰ slopes. Planting grass lines protect the slope and conserve the soil as they reduce the speed of run off with the help of their roots. This method is applied on 35⁰-60⁰ slopes. The planting of large bamboos reduce movement of slope material and stabilise slope in the upper the Beas basin area.



Figure 6: Apple Orchard Near Palchan Village, Manali

Some other methods like grass seeding, tree or shrub seeding, bamboo planting and turfing reduce landslides impacts and it holds some potential applicability between Kullu-Rohtang Pass area.

4.2.2 Proper Utilization of Land

The land use planner should make the local people understand about the importance of land use planning. But deforestation, urbanization, industrialization, exploitation of resources, heavy building construction and engineering structural work, etc. increase the landslide vulnerability. Thus, proper scientific land use planning and ban on non-biodegradable materials is the need of the hour. The scientists and engineers should arrange mass awareness camps to increase geological, geo-hydrological investigation practices. They also make local people understand about the importance and uses of eco-friendly building materials in landslide prone areas. The afforestation programmes should be effectively implemented as the preventive measures for the landslides (Figure 7). The selection of suitable plants species should be done in such a manner that can reduce the existing stress conditions of the terrain.



Figure 7: The Afforestation Programme Near Kulang Village, Manali

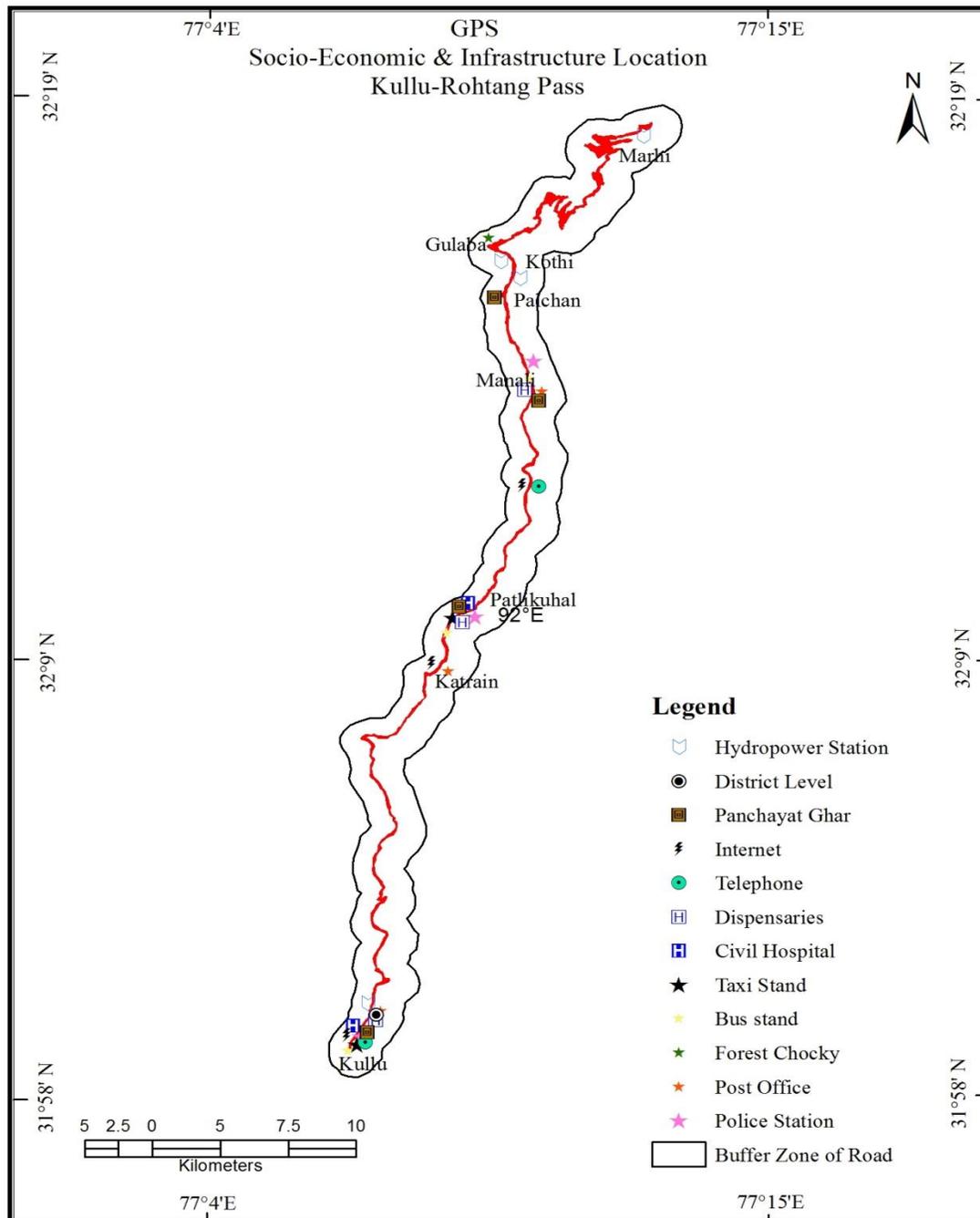
4.2.3 Socio-economic and Infrastructural Database

The socio-economic and infrastructural database system plays an important role in landslide disaster management during emergency and post emergency phases. An extensive field survey using GPS was carried out to locate and to map available socio-economic and infrastructural facilities required for the management of landslide disaster and mitigation of their risks in the study area (Figure 8). Community buildings also play a vital role during rescue and relief phase . There are only 4 community buildings in the study area (Table 1).

Table 1: Existing Socio-economic and Infrastructural Database, Kullu-Rohtang Pass, 2016

Socio-economic and Infrastructural Database		Existing	GPS Kilometer Location
Administrative centers	Police station	3	Kullu (0.7), Patlikuhal (23.7), Manali (38.2)
	Patwari station	1	Kullu (1.5)
	Post office	4	Kullu (2.0), Patlikuhal (21.3), Manali (37.4)
	Forerst chocky	1	Gulaba (60.4)
Transportation	Bus station	3	Kullu (0.0), Patlikuhal (22.5), Manali (38.0)
	Taxi station	2	Kullu (0.1), Manali (38.0)
Medical centers	Civil hospital	2	Kullu (0.3), Manali (38.3)
	Dispensary	3	Kullu (0.9), Patlikuhal (22.6), Manali (37.1)
Public communication centers	Telephone	3	Kullu (0.4), Manali (38.6), Katrain (31.4)
	Internet	3	Kullu (0.4), Manali (38.6), Katrain (31.4)
Community bulding	Panchayat ghar	4	Kullu (0.5), Patlikuhal (22.8), Manali (36.3), Palchan (51.1)
Disaster interpretation center	District level	1	Kullu (0.9)
Water supply	Hydropower stations	4	Kullu (2.1), Palchan (51.0),Kothi (54.6) , Marhi (84.3)

Source: Field Survey, 2016



Source: Prepared by Author

Figure 8: Socio-Economic and Infrastructure Location Between Kullu-Rohtang Pass

5. PEOPLE’S PERCEPTIONS REGARDING LANDSLIDE RISK MITIGATION

5.1 People’s Perceptions Regarding Techniques and Practices to Mitigate the Occurrence of Landslide Events.

The basic skill knowledge, technical expertise, economic status and level of mass awareness of local community are the important tools by which we can control and mitigate the landslide risk between Kullu-Rohtang Pass. The control over deforestation, afforestation, toe-wall and slope-based construction programmes in the study area are the four most preferred techniques which have reduced the impact of landslide risk and mitigate the occurrence of landslide events (Table 2). All the 200 respondents have shown their 100 per cent dedication and keenness to undertake these four mitigation techniques in landslide hazard control.

Table 2: People’s Perceptions Regarding Techniques and Practices to Mitigate the Occurrence of Landslide Events

S. No.	Mitigation Techniques	Landslide Hazards	
		No. of Respondents	Percentage
1.	Afforestation	200	100
2.	Control over deforestation	200	100
3.	Construction of reservoirs	180	90
4.	Control on overgrazing	150	75
5.	Better drainage techniques on slopes (along the road)	172	86
6.	Agro-forestry	38	19
7.	Control on construction of houses in the vulnerable area	93	46.5
8.	Proper utilization of land	140	70
9.	Check on urban sprawl/ tourism	35	17.5
10.	Toe-wall	200	100
11.	Slope based construction	200	100
12.	Planting trees on slopes	104	52
13.	Others	00	00

Source: Based on Primary Survey

Apart from the above four mitigation techniques, the construction of reservoirs and better drainage techniques on slopes are the important techniques responded by 180 and 172 respondents respectively. Control on overgrazing and proper utilization of land are also other two important mitigation techniques to control and mitigate landslide hazard occurrences responded by 150 and 140 respondents respectively. In the study area, only 17.5 per cent respondent's perception is along with the check on urban sprawl/ tourism mitigation techniques for reduce the landslide risk.

5.2 People's Perceptions Regarding Awareness of Government Initiatives to Mitigate the Landslides.

A better understanding between government initiatives and local community participation plays an important role to mitigate the landslide events. The local communities between Kullu-Rohtang Pass have very strong faith and high appreciation for the government initiatives in construction of toe-wall and afforestation programmes. 100 per cent respondents have shown their positive perception for construction of toe-wall as well as afforestation programmes (Table 3).

Table 3: People's Perceptions Regarding Awareness of Government Initiatives to Mitigate the Landslides

S. No.	Government Initiatives	Landslide Hazards	
		No. of Respondents	Percentage
1.	Construction of check dam	185	92.5
2.	Afforestation	200	100
3.	Posting danger zone sign	195	97.5
4.	Campaigning through media	143	71.5
5.	Making stone-toe wall	200	100
6.	Establishment of slopes by plant cover	70	35
7.	Forecasting/warning by different departments	50	25
8.	Others	00	00

Source: Based on Primary Survey

In the landslide prone areas, the government of Kullu has displayed danger zones signs to prevent casualties. 195 respondent's perception is positive regarding government initiatives. Campaigning through media is also another good initiative by government for landslide mitigation in Kullu valley.

5.3 People's Perceptions Regarding Initiatives of the NGO's to Mitigate the Landslides.

The social development of any place, region or community is reflected by their social and economic activities. A large number of Non-Governmental Organizations (NGOs) are engaged in social activities. The upper part of the study area is a typical mountainous area having a large scope for development for the NGOs. Cooperative societies in Kullu like Himalayan Adventures Cooperative Society, Mahila Cooperative Agricultural Service Society, etc. are working for the mitigation of landslide events. The afforestation initiatives by NGOs for the mitigation of the intensity of landslide occurrences has been liked by 200 respondents (Table 4).

Table 4: People's Perceptions Regarding Initiatives of the NGO's to Mitigate the landslides

S. No.	NGO's Initiatives	Landslide Hazards	
		No. of Respondents	Percentage
1.	Construction of check dam	00	00
2.	Afforestation	200	200
3.	Posting danger zone sign	30	15
4.	Campaigning	70	35
5.	Opposing urbanization & Tourism	30	15
6.	Education for mass awareness	25	12.5
7.	Financing	00	00
8.	Others	00	00

Source: Based on Primary Survey

The campaigning of the occurrence of landslide hazard are also done by NGOs. In the study area, 70 respondents are in favour of this NGOs initiative. The programmes for opposing urbanization and spread of education for mass awareness were also initiated by the NGOs to control and mitigate the impacts of landslide hazard. About 15 and 13 per cent respondents have replied in a positive way regarding the initiatives of the NGOs to mitigate landslide hazards.

5.4 People's Perceptions Regarding Village Level Performance to Mitigate the Landslide Events.

The perception and positive involvement of community in any decision making process at village level is good for the mitigation of landslide risk. The upgraded level of awareness generates integrated development of society or collective approach which is able to face any problem and create new innovative ideas. The panchayat level or bottom to top level approach has been adopted to control landslide hazard. Social forestry programme at village level between Kullu-Rohtang Pass is done mainly for the mitigation of landside occurrences (Table 5). On an average about 97.5 per cent of respondents have shown their positive perception for this programme to control landslide hazard.

Table 5: People's Perceptions Regarding Village Level Performance to Mitigate the Landslide Events

S. No.	Performance	Landslide Hazards	
		No. of Respondents	Percentage
1	Social forestry	195	97.5
2	Construction of check dam	148	74
3	Helping government personnel	130	65
4	Mass level campaign	40	20
5	Opposing the tourism and urbanization	57	28.5
6	Others	00	00

Source: Based on Primary Survey

The construction of check dam is also done by the village panchayat. On an average 74 per cent respondents acknowledge this activity. In the study area, people are also involved with government personnels by visiting different departments and providing latest information relating to the probability of landslide occurrences. 65 per cent respondents favoured this standpoint. The mass level campaigns related to landslide mitigation is also done by a limited number of respondents in the study area.

5.5 People’s Perceptions Regarding Individual Efforts to Mitigate the Landslide Events

The people’s perception observed in study area is very positive and optimistic as 180 respondents are in favour of plantation of trees and are willing to do on individual level, 82 respondents are even ready to do villiage level campaigning for spreading mass awareness in order to mitigate the landslide events and 42 respondents replied in favour of opposing the tourism and urbanization (Table 6).

Table 6: People’s Perceptions Regarding Individual Efforts to Mitigate the Landslide Events

S. No.	Individual Efforts	Landslide Hazards	
		No. of Respondents	Percentage
1.	Plantation of trees	180	90
2.	Visiting different departments and collecting information	38	19
3.	Village level campaign	82	41
4.	Helps through NGO’s	10	5
5.	Financial helps	5	2.5
6.	Campaigning through media	16	8
7.	Opposing the tourism and urbanization	42	21
8.	Others	00	00

Source: Based on Primary Survey

The campaigning through media and individual efforts like visiting different departments and collecting information is also done by a limited number of respondents.

5.6 People’s Perceptions Regarding Awareness of the Institutions in Controlling the Landslide Events.

Research on landslide hazard mitigation between Kullu-Rohtang Pass also includes the level of awareness and perceptions of the local people’s regarding the institutions that are engaged in monitoring and controlling the landslide hazard events. In the study area, Border Road Organization (BRO), Snow Avalanche Study Establishment (SASE), Western Himalayan Mountaineering Institute (WHMI), Public Work Department (PWD), Health and Irrigation Department (HID), Divisional Forest Office (DFO), Himachal Pradesh Tourism Development

Corporation (HPTDC) and District Revenue Office (DRO) are positively working for landslide hazard mitigation (Table 7).

Table 7: People's Perceptions Regarding Awareness of the Institutions in Controlling the Landslide Events

S. No.	Institutions	Landslide Hazards	
		No. of Respondents	Percentage
1	Border Road Organization (BRO)	200	100
2	Snow Avalanche Study Establishment (SASE)	173	86.5
3	Western Himalayan Mountaineering Institute (WHMI)	48	24
4	Public Work Department (PWD)	200	100
5	Health and Irrigation Department (HID)	30	15
6	Divisional Forest office (DFO)	45	22.5
7	Himachal Pradesh Tourism Development Corporation (HPTDC)	18	9
8	District Revenue Office (DRO)	00	00
9.	Any other Institution	00	00

Source: Based on Primary Survey

Border Road Organization (BRO) has been highly applauded by all 200 respondents for controlling the landslide hazard between Manali-Rohtang Pass followed by Public Work Department (PWD) between Kullu-Manali while 173 respondents are in the favour of Snow Avalanche Study Establishment (SASE) working for monitoring the landslide and snow avalanche hazard.

6. CONCLUSION

It can be concluded that the proposed integrated landslide risk mitigation plan can be classified into pre-disaster, during-diastar, post-disaster phases, which are based on the engineering and non- engineering mitigation methods. Strategies for landslide awareness generating programmes by social as well as administrative systems, have been helpful in the mitigation of the impacts

of landslide events in the study area. Early warning systems such as Geographical Information System (GIS), Remote Sensing (RS), Global Position System (GPS) are proved to be useful towards landslide disaster management, preparedness and mitigation at all levels. GPS based socio-economic infrastructural location mapping has emerged as the boon for it is used for the community evacuation plan which is based on place centered mapping. Primary survey of people's perception regarding landslide risk mitigation is the main source to know the awareness and preparedness level of the local communities. In the nutshell it can be said that there is a positive response for the techniques and methods implemented by the government and even local people are ready to participate in the process if given a chance to mitigate the landslide risks.

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