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Landslide Risk and Mitigation Strategy: A Case Study of Kullu Valley, India

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Abstract: Landslides are defined as the movement of rocks, debris, and landfills under the influence of gravity. Slide is one of the most common types of accidents on slopes, which can lead to serious injuries and economic losses. Each year, natural disasters cause more deaths and more damage to infrastructure and the environment. In 2004-2005, more than 200,000 people lost their lives in natural disasters. Material damage is estimated at USD 300 billion. Many lives would have been saved if more had been known about prediction and mitigation. In the hilly areas of the Himalayas, landslides have become a major and widespread natural disaster and often have a detrimental effect on life and property and have been a source of great concern. Kullu in India is a highly vulnerable city due to many natural and man-made disasters. One of the most common natural disasters is landslides caused by heavy rains, floods, earthquakes and erosion, and anthropogenic factors. In Kullu, a total area of 5401 (square km) is at risk of landslide. The paper introduces the latest work to assess, mitigate and control the risk of landslides. Other important and important ways to control landslides are also introduced.

Keywords: Landslide Risk, Natural Disasters, Anthropogenic Factors, Landslide Mitigation

1. Introduction:

Landslides are a major geologic hazard that includes all forms of massive hill slopes caused by the failure of objects such as rocks, soil, debris, artificial filling driven by gravity. Landslides cause severe health losses and damage to communication lines, human settlements, agricultural fields and forests. Natural disasters, including floods, landslides, and landslides caused by heavy rains and hurricanes, occur almost every year in the Republic of Korea. In Seoul, the annual average of landslides caused over the past 15 years has reached 243 hectares and resulted in the loss of 56 lives per year. Therefore, measures to prevent natural disasters should be carefully managed. In India, with the exception of ice regions in the north, approximately 0.42 Million km2 of land area (12.6%) is prone to collapse and spread to 19 unusual areas covering more than 65,000 villages in hilly / mountainous areas. In the Kullu district, an area of 5401 (square km) is at risk of landslides. Slope failure is also a major cause of landslides in the Klulu district. The diversity of slope sections, degradation processes, subtropical climates, soil texture, natural and chemical properties and random growth of habitats have led to recurring landslides in the Kullu

Valley (Singh, 1991). A low-level approach can aid in the effective implementation and implementation of mitigation and non-structural measures to reduce the risk of collapse and control with the help of NDMA, NIDM and GSI (National Disaster Management Guidelines, 2009). In recent years, the mountains surrounding the urban areas have been used for major residential development, due to the rapid increase in urban populations. Occasionally, houses were built even on the upper hills, ignoring the safe disposal of much of the rainwater. This type of land use change sometimes provides a major cause of slope failure and landslides. Special types of prevention activities are needed in areas with high risk of landslides.

2. Study Area:

Kullu Valley is known as the famous tourist destination in India. The Kullu Valley is high in the Himalayas and enjoys tropical climates all year long. The area causes heavy rainfall during the rainy season between July and September. The area receives moderate rainfall during the winter and in the form of rain and snow. In the Kullu district, the tourism sector enjoys a very important role for citizens and government and therefore, the government ensures that all available opportunities are provided to the tourism sector by building the necessary infrastructure for growth and expansion as a means of transport, community utilized services, water supply and better communication network etc. Figure 1 shows a map of the Kullu valley.

3. Data Sources and Methods of Analysis:

The research is based on secondary data sources. According to the Kullu valley context, secondary information has been collected from various government reports (NDMA, NIDM, and DDMP), magazines, research papers and articles. Major sources for natural disasters, including landslides, have been published by the Department of Home Affairs (MOHA), the Department of Agriculture and Forestry (FA).

An integrated approach to reducing the risk of landslides has been chosen to reduce the risk of collapse in the present study (Figure 2).

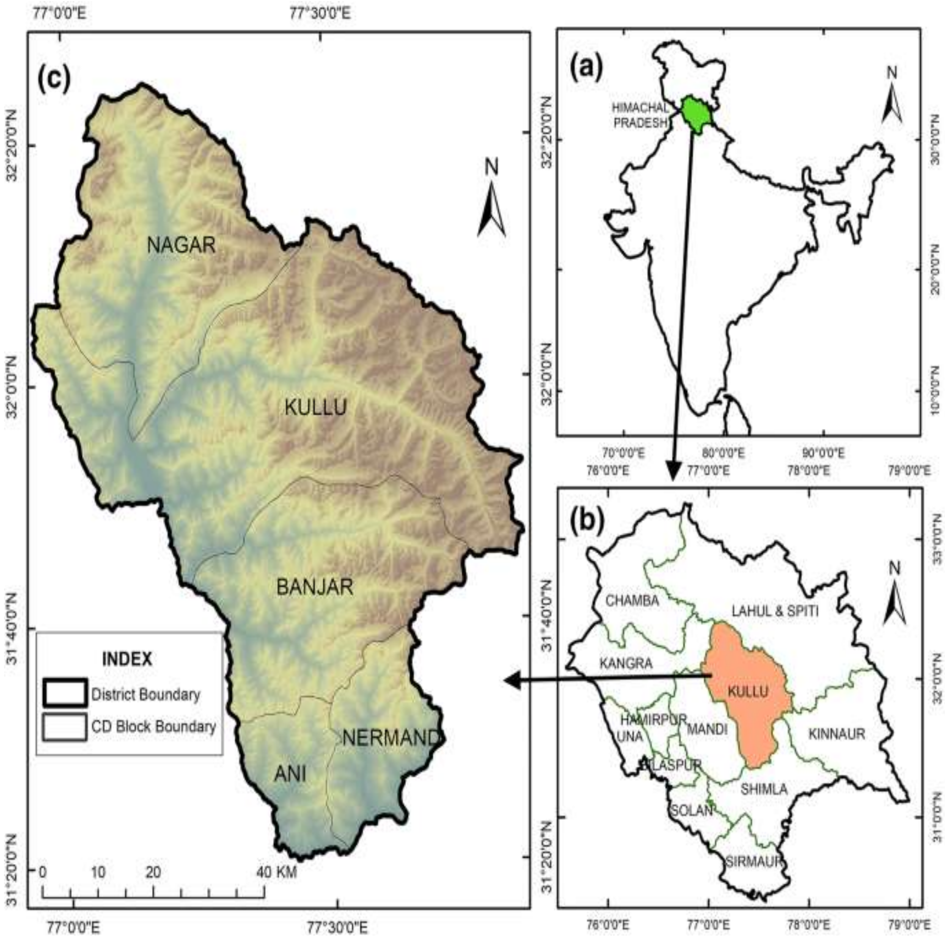


Figure 1: Location of the Study Area (Kullu)
Source: Nemai Sahani, 2018

4. Integrated Landslide Risk Mitigation:

The integrated mitigation approach includes various engineering and non-engineering techniques, landslide risk mitigation plan, disaster prediction, preparedness and management (Tucci and Petry, 2006; Yan et al., 2006; Alphen and Lodder, 2006).

The basic mechanism of landslide risk mitigation can be divided into three phases of disaster i.e. Pre-disaster, Emergency and Post-disaster phase (Figure 2).

1. **Pre-disaster phase:** This stage includes the study of potential landslide disasters, analysis of vulnerability and assessment, monitoring, prediction, forecasting, formulation of landslide disaster prevention and preparation of mitigation plans and capacity building programmes by increasing level of community awareness etc.

2. **Emergency phase:** This stage involves effective search and rescue operations, evacuation and relief operations during landslide disaster.

3. **Post-disaster phase:** This stage involves the ground work related to socio-economic and environmental rehabilitation in the affected area.

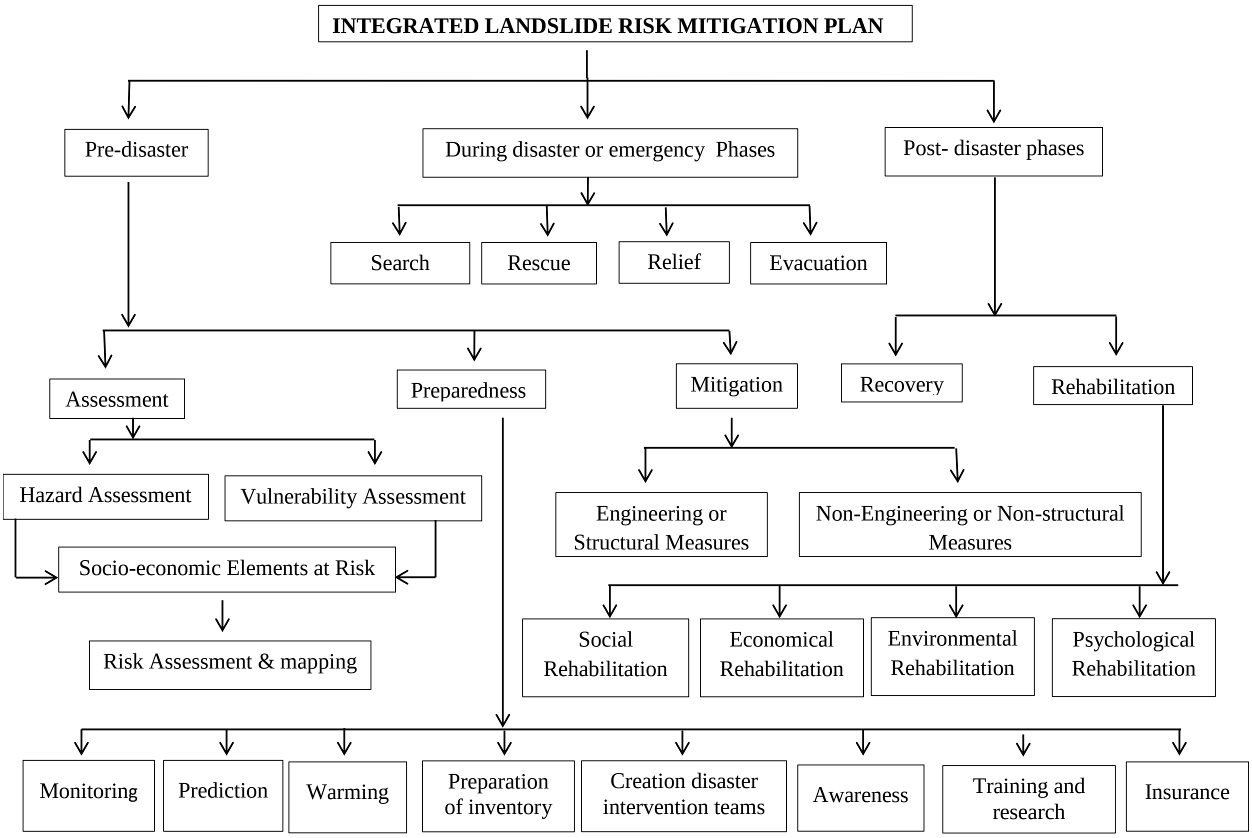


Figure 2: Integrated Landslide Risk Mitigation Plan
Source: Prepared by Researcher

Landslide Disaster Prediction

Predicting landscapes requires a mapping of the landslides and identifying the time and place. For landslide mitigation control measures, one needs to be aware of landslide fragmentation, potential mechanisms of failure, and the characteristics of the landscape shear and the performance of landslides. Early warning systems are part of the preparedness plan for any disaster-prone area. Remote Sensor, Geographic Information System (GIS), digital image processing and Global Position System (GPS) techniques are often used to analyze region and predict endangered areas. Doppler radars geo-stationary weather monitoring satellites have greatly improved the ability to predict weather-related disasters and reduce the effects.

Special government agencies usually do three warning parts:

(i) Prediction based scientific analysis

(ii) Decision on when to work

(iii) Communication warning

Landslide Disaster Preparedness

It is a very effective practice at all levels and management plans to save lives by minimizing damage in the event of a natural disaster (Eistein, 1987). Comprehensive disaster preparedness includes community education, community-based planning, villain awareness, campaigns, evacuation plans and providing emergency shelter, water and food. The construction of roads, houses, and other infrastructure increases the risk of landslides in popular areas such as the Kullu valley and the Seoul region. Earthquake and evacuation readiness can reduce the causes and damage to property. Public education programs help people understand the causes and effects of landslides in addition to helping them identify unstable areas and avoid settling there. The pre-disaster preparedness phase is more important than the post-disaster preparedness phase. Disaster preparedness is needed at all levels from home to central government, in order to minimize the impact of disasters. The government will not be able to immediately reach every village and village during a disaster. The community is the first responder to any disaster and develops specific response strategies to reduce their risk over the past decades. Public participation at the grassroots level is an important factor in any disaster preparedness. Community-based disaster preparedness is:

(i) Response to saving lives, livelihoods, livestock and property through community resources.

(ii) It leads to multilateral development interventions to address the root cause of vulnerability.

(iii) It leads to an independent community that is resilient to disasters.

In order to reflect the readiness and responsiveness of the people, Community Based Disaster Preparedness Programs (CBDP) should be implemented in all vulnerable areas. The community in a disaster-prone area decides to pursue a list of activities that fall under the CBDP to reduce the loss of life, livelihood and property. It also identifies in advance the steps that should be taken by individuals in the community so that everyone is aware of their responsibilities when an emergency warning is received. In addition, communities can reduce the risk of landslides by building strong structures, compacted land, preventing deforestation, stabilizing slopes through canals and forests, and creating rock falls using trees and landslides (Haigh et al., 1987).

5. Major Landslides in Kullu valley

The most damage causing landslides events in the Kullu valley are:

- Luggar Bhatti (12 September 1995). 65 people were buried alive during slide.
- Nehru Kund, Manali (17 March 2008). Massive landslide boulders blockedcompletely damaged NH-21 road corridor, 6 people died and 13 injured.
- Manali (5 March 2011). Blocking of roads, electricity breakdown, and traditional house collapsed in Malana village.
- Manali (26 February 2011). Terraced fields damaged, tress fell down, traffic jam at Dobhi, Raison and Manali.
- Manali-Leh Highway (16 September 2012). Manali to Leh (NH-21) blocked and heavy traffic jam.

- Kullu-Anni (28 August 2013). Kullu-Ani highway blocked, transport and communication disturbed.

- Kullu-Anni (28 August 2013). The Kullu-Anni highway was blocked in two areas and residents of 58 sub-village panchayats in Anni and Nirmand in the Kullu sub-district have been unable to contact the regional headquarters for about a week.

- Manikaran Gurudwara Kullu (18 August 2015). A 3-room building in Gurudwara was destroyed, leaving 7 passengers dead and 11 injured in an estimated loss of Rs. 29.10 lakh.

- Pancha Manihar Road at Parbati HE Project, Stage-II, Kullu (2 September 2016). Total 9 persons (5 killed & 4 injured) were buried alive during the slide.

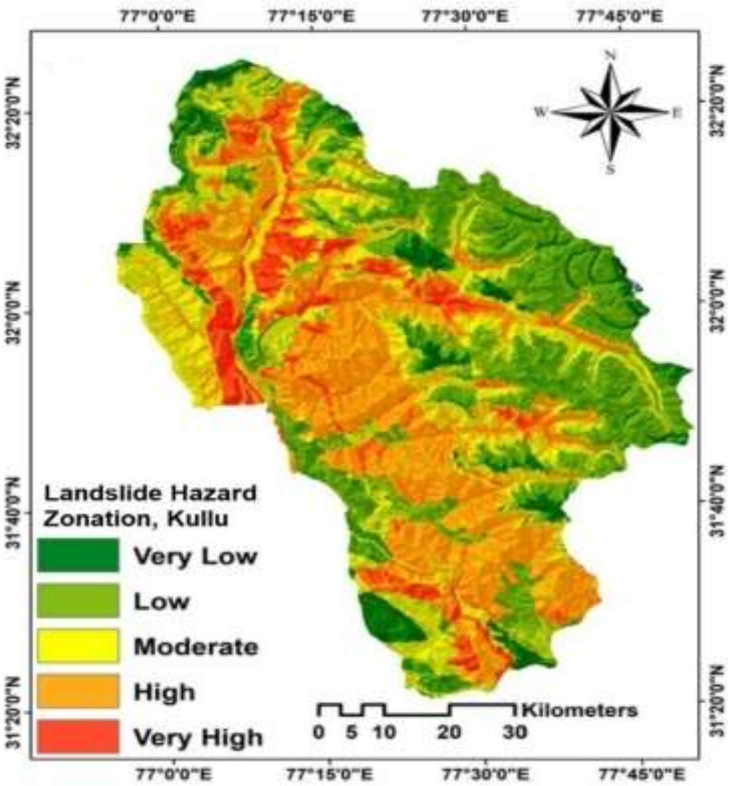
- Manali-Leh Highway (7 August 2018).Massive landslide occurred near Marhi in Manali sub-division. Landslide has blocked highway

Source: "Nehru Kund". 32.285885°N and 77.179539 ° E. Google Earth. November 11, 2010. March 17, 2018

Massive Landslide Boulders and Mud Blocked NH-21, 17 March, 2008

6. Landslide Hazard Zonation in Kullu valley

Landslide Hazard Zonation (LHZ) mapping is an efficient tool used for detecting landslide affected sites and calculating the possibility of landslide occurrences in a particular span of time. The LHZ mapping has been applied for various sites in hilly areas around the world. Wagner et al., (1988) presented rock and debris slide risk maps for road alignment with the help of geological, structural, slope, and geomorphological factors. In Kullu valley, many experts have successfully attempted to implement LHZ mapping in landslide vulnerable areas with the help of considering factors and the nature of the terrain. LHZ maps are very helpful in identification and delineation of hazard prone areas for initiating suitable mitigation measures in time.With the help of LHZ maps, the planning authorities choose appropriate and adequate locations for developmental schemes and projects such as roads, dams, bridges and townships developments.LHZ maps have a range of potential uses for land use at both regional and national level.LHZ maps help the authorities in prompt decision making process for rescue and relief operations.



7. Landslide Risk Mitigation Methods

The task of landslide hazard mitigation has to be a coordinated effort of the local authorities, state government, central government and other stakeholders living in 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 valley pass area can be effectively controlled; however, it requires proper management and planning with sufficient financial resources and follow up of engineering and non-engineering landslide mitigation methods (Table 1).

Table 1: Engineering and Non-Engineering Landslide Risk Mitigation Measures in Kullu valley

1. MODIFICATION OF SLOPE GEOMETRY
1.1. Removing material from the area driving the landslide (with possible substitution by lightweight fill) 1.2. Adding material to the area maintaining stability 1.3. Reducing slope angle
2. DRAINAGE
2.1. Extra drains to divert water from the slide area (collect drainage and pipes) 2.2. Shallow or deep trenches filled with free geo-draining materials (granular fillers and geo-synthetics) 2.3. Vertical (small diameter) boreholes with pumping or self draining 2.4. Sub-horizontal or sub-vertical boreholes 2.5. Drainage channels 2.6. Vacuum dewatering 2.7. Vegetation planting (hydrological effect)
3. RETAINING STRUCTURES
3.1. Walls that retain gravity 3.2. Gabion walls 3.3. Cast-in situ reinforced concrete walls 3.4. Reinforced structures that keep the earth in line / sheet - polymer / metallic reinforcement elements 3.5. Retention nets for rock slope faces 3.6. Rockfall stopping systems (rocktrap ditches, benches,fences and walls) 3.7. Protective concrete blocks against erosion
4. INTERNAL SLOPE REINFORCEMENT
4.1. Rock bolts 4.2. Soil implantation 4.3. Grouting 4.4. Columns of stone or lime 4.5. Vegetation planting

Source: Prepared by Researcher

8. Conclusion

The landslide frequently poses challenges in areas of engineering. Landslide hazard analysis and mapping can provide useful information on reducing catastrophic losses and assist in the development of guidelines for sustainable spatial planning. Analysis is used to identify factors related to landslides, to estimate the associated impact of slope failures, to establish relationships between objects and landslides and to predict future erosion risk of site consolidation based on such relationships.

In the Kullu Valley region, natural disasters including floods, landslides and landslides caused by heavy rainfall associated with hurricanes cause significant loss of life and damage to property and the environment. There have been 30 major disasters during the last 20 years. Landslides in these regions are caused by soil erosion with high rainfall patterns and / or high rainfall strength. Government should develop new ways to prevent natural disasters in such areas of land use change, especially on steep slopes. In order to rehabilitate landslides, reinforced concrete structures and retaining screens are highly recommended.

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