Review on Landslide Hazard Management at Himachal Pradesh

Sachin Verma¹ Vidya Sagar Khanduri²

¹ M. Tech Scholar, School of Civil Engineering, Lovely professional university, Phagwara, India
² Assistant Professor, School of Civil Engineering, Lovely professional university, Phagwara, India

Abstract
State of Himachal Pradesh in India suffer from various natural and manmade hazard. Although there are many hazards consists of earthquake, snow, storm, dam failure but landslide is one of main hazard in state which occur mostly at monsoon season. Aim of current study is to understanding current state of knowledge in term of managing landslide hazard at Himachal Pradesh. State has well establish policy of managing the disaster of landslide in the state. It is observed that various use of GIS in preparing landslide susceptibility zonation map is main prevention technique whereas geotechnical investigation of soil to help in understand mechanism of failure it also helps to deciding possible mitigation technique possible failure slope. Use software like plaxis 2d is found highly effective to analyzing slops and effectivity of solution.

Keywords: Landslide, landslide susceptibility zonation, GIS, Plaxis 2d, Geotechnical investigation.

1. Introduction
In last few year it has been observed that events of landslide have been increased in Himalayan mountain series, but it is observed that no enough work is done in understand these landslide and factor responsible[1]. Himachal Pradesh is hill state of India.it is divided into three zone physiographically. The outer Himalayas (Shivaliks) The lesser Himalayas (central zone) The Great Himalayas (northern zone) each range have different litho-tectonic setting such as the Siwalik, the Lesser and the Great Himalayan. As describes by state policy on disaster management there are various natural and manmade hazard on state. Main hazard consists of earthquake snow storm dam failure and landslide. Although landslide occur all the year but monsoon is most crucial time for landslide. Due to various factors like increase in overall rainfall, deforestation and road construction vulnerability of landslide is increasing [2]. Petley in his research found that maximum number of death due to landslide in world is located at Himalayan arc and China.[3] A typical DM continuum comprises of six elements; the pre-disaster phase includes prevention, mitigation and preparedness, while the post disaster phase includes response, rehabilitation, reconstruction and recovery. A legal and institutional framework binds all these elements together (Diagram 1). Himachal Pradesh State Disaster Management Policy continuum consist of different element. It compromises of different element as disaster management cycle. As described in fig1. Broadly work in term of landslide is done on providing different remedy to landslide and preparation of landslide susceptibility zonation map although some work is also done on post disaster analysis of landslide. GIS today enable different application in term of landslide management it allows analyzing different map of area and preparing prediction map by different approaches which is mainly distinguished as direct and indirect approach. Using geomorphology to map hazard of landslide is used in direct method while use of causative factor to map while giving different value to different factor is mostly involved in indirect method. Use of indirect method is mostly observed in scientific literature [4] Although landslide zonation map for full country is provided by NDMA but not such zonation map for state is provide by state DM policy. Aim of current study is to understanding current state of knowledge in term of managing landslide hazard at Himachal Pradesh.
2. Landslide susceptibility zonation

Landslide susceptibility is basically Spatial prediction of landslide which generally depend on various causative factors. Generally, we tend to predict locations which are more venerable landslide compare to other depending on previous landslide and possible factors. Although there are many approaches of landslide but it is basically distinguished as qualitative and quantitative approach.[5]

2.2 LSZ work at Himachal Pradesh

2.2.1 Sharma, S., & Mahajan, A. K. (2019)

LSZ map of city Dharmsala was developed using Information value method. Location of different landslide was observed by site visit and confirmation was done using GPS. Information value approach is used in the literature to develop map of area. Suspected causative factor used in their research was lithology, aspect, soil type, fault density, land cover, slope, drainage density. Landslide was plotted on map of area and pixel value of each landslide is observed using ArcGIS software. The maximum data available is used to assess the causes of landslides in the study area. They have used 30m resolution ASTER GDEM and images from google Earth to map land cover. they found slope, aspect and drainage network using ASTER GDEM and with help of ESRI ArcGIS software. Information value (In V) method is used for landslide susceptibility zonation of Dharmsala region. Number Pixel of different classes in every factor and number of pixels of landslide in each class is observed in aim to find information value. Information value of every subclass is then used to overlap maps layer using different tool ArcGIS software and landslide susceptibility map is...
obtained. Five different class of new LSZ map was used to distinguish susceptibility as very low medium high and very high class of susceptibility. Out of total landslides 0.66 sq. km, 0.65 sq. km landslide fall in very high susceptibility class.[6]

![Landslide susceptibility zonation map of Dharamshala.](image)

Fig. 3 Landslide susceptibility zonation map of Dharamshala.

2.2.2 Pandey, V. K. (2019)

The aim of this examination is to research the reasons for different landslide in the Himalayan area and investigation of their sedimentary qualities. Himachal Pradesh distinguished geography as, the Siwalik, the Lesser and the Great Himalayan ranges. study, a highway is chosen going through the Siwalik and the Lesser Himalayan range. For conduct of this research highway corridor of rajgarh-nahan was selected. Firstly, characteristics of landslide was observed by repeated visit to site. 34 landslides were examined in their study along highway. Different perimeter like height, width, soil moisture type of fall and land cover was observed. It was observed that small scale landslide was more common. debris flow, slide, fall and rock slide was mostly observed. It was concluded that slope was main factor of landslide to occur at highway while slope toward river was due to river undercutting process. Further in their research different geotechnical test was conducted on soil sample they have collected from two location to understand different character of soil of landslide. Grain size distribution, liquid limit, in situ rock strength test was conducted. less content of fine particle at location give indication high porosity due to which rain water can easily seep. Regular cultivation above slope area also play crucial role in increasing water content of slope. At location 2 many cracks were observed which play important role. Result of rock strength shown very less value of strength as 15.3Mpa steep inclination of slope was other character of slope. best susceptibility zonation map by comparing results from different approach was also done in their study. Various technique used ban be RF (random forest), BRT (Boosted Regression Tree, SVM (Support Vector Mechanism), GLM (Generalized Linear Model). Total of 12 factors was selected in there study including aspect, plan curvature, slope, profile curvature, stream buffer topographic wetness index, road buffer fault, type of soil, land use land cover, lithology, geology map. Highest success rate was observed using RF approach with 90% success rate which is verified using AUC.[7]
2.2.3 Singh, K., & Kumar, V. (2017).

In this study LSZ map was developed in highway corridor of NH154A which goes from Bharmor to Chamba. Two methods were used and compared which are frequency ratio method and information value method. Different causative factors responsible for landslide considered in his study were slope, aspect, Land Use and Land Cover, soil type, curvature, lithology, relative relief drainage density, and lineament density. While use of DEM was done to extract slope, aspect, relative relief and curvature map, other map was collected from different government department. Nine classification of lithology is used in his study which Phyllites/slates cover maximum area whereas Dark gray slate, micaceous sandstone and quartzite lithology contribute maximum to landslide six classification for LULC was considered in which maximum area was found to be under Barren land which also contribute maximum to landslide. Coarse loamy type of soil was found to be distributed maximum whereas loamy soil found to biggest contributor of landslide. Different perimeter was also observed. [8]

Table 1 area of each class by information value method and frequency ratio method.

<table>
<thead>
<tr>
<th>methods</th>
<th>Information value method</th>
<th>Frequency ratio method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard zones</td>
<td>Area (%)</td>
<td>Landslide area (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very low</td>
<td>15.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Low</td>
<td>29.99</td>
<td>9.41</td>
</tr>
<tr>
<td>Medium</td>
<td>26.93</td>
<td>16.00</td>
</tr>
<tr>
<td>High</td>
<td>15.75</td>
<td>23.22</td>
</tr>
<tr>
<td>Very high</td>
<td>11.93</td>
<td>49.87</td>
</tr>
</tbody>
</table>

Using AUC results it is observed information value method provide better prediction rate which is 78.87% as compare to frequency ratio method which is 75.37%.

Fig. 4 Landslide susceptibility zonation map of NH154A.

2.2.4 Chandel, V., Brar, K. K., & Chauhan, Y. (2011)

Landslide hazard zonation map of area was developed using multivariate criteria analysis at Kullu district of Himachal Pradesh. Imageries from LANDSAT ETM+ and IRS P6 satellite was used to extract land use data in special resolution on 15m. DEM data of ASTER satellite was used to extract parameter like aspect, drainage density and slope. Field visit data was collected with using GPS Coordinates so that location of landslide can be plotted on GIS. Lithology of area
is observed using geological map of area. Total of seven perimeters was used as causative factor in study consist of slope, aspect, Relief, Physiography, lithology, Drainage density and land use. total of 49 landslide was considered in his study. final LSZ map of Kullu shown zero risk zone is 0.42 percent total area, Low to Moderate is 19.42 %, High is 48.16 % whereas Very High to Severe is 32.00% area. Which show almost 80% area is falling under high to severe zone in Kullu which show high requirement of landslide mitigation and remedial measure.[9]

3. Landslide mitigation

Group of solution are in combination are generally used for landslide prevention possible solution to be select at site is generally require field investigation and understanding of both causative and trigging factor. Understanding mechanism of failure help engineers to selection of best possible remedy to landslide and mitigation to possible vulnerable slope. many authors classify solution in in four groups namely change in slope geometry, drainage, retaining structure, internal slope reinforcement.[10]


sharma has worked on providing possible mitigation to landslide at kotropi landslide occored on 2017 in first step of research collection of total 27 samples from site was done from different location of landslide and performing various geotechnical test on the lab which brodaly cosist of, Atterberg’s limit, triaxial test, chemical analysis, compaction test, grain size analysis, direct shear. It is important to note that soil was classified as SP-SM. Chemical test was also analyzed to understand long term safety of nail as PH more than 7 is not recommended in term of nail safety when PH value of soil is investigated it reviled value as low as 6.5 and up to maximum of 7 which was pretty much safe condition. Helical soil nail was preferred compare to conventual nail because of more vibration occur to driving and installation of conventional nail lead to high damage to surrounding soil whereas installation of helical soil nail is more of torque oriented. Various calculation was done in research to fin dimension of nail which was found to be 6m in length and inclined at 15°. height of overall slide to be stabilze was 30 m but it was cut into section of 10 m each so that more safety can be achieved spacing for nail was 1m in each vertical and horizontal direction. Further to analyses the safety of this slop after stabilization numerical model of slope was made in Plaxis 2d software to analyze new factor of safety. Further calculation was done to calculate axial stiffness and bending stiffness of nail. Whose value can be used in
modeling. Axial stiffness used here was $0.0628 \times 10^{-3}$ KN/m whereas bending stiffness for nail was $2.093 \times 10^{-9}$ kN-m/m. Factor of safety, deformation and stresses on soil nail was main key factor to be analyzed. Analysis has shown increase of FOS from less than one in initial slope to 1.67 where as deformation was reduced from 0.13m to 0.06m. most of nail was observed under tension force as no intersection of nail was observed with failure surface.[11]

![Image of Landslide at kotropi.](image)

**Fig.5 Image of Landslide at kotropi.**

4. Conclusion

Review was done with aim to understand current state of knowledge in term of managing landslide hazard at Himachal Pradesh following can be concluded from this review. Although state has well establish policy of managing the disaster of landslide in the state but lack of work is observer in term of various prevention/mitigation technique like Vulnerability Mapping in term of Preparedness like Early warning system Response by Provide remedial measure. Landslide susceptibility zonation prepared using GIS software found to be very effective solution as this zonation map highly effective in decision making by different stakeholder, decision maker and engineers in decision like location of construction, route for new roadways, proper traffic flow. There is no landslide susceptibility zonation map available on many districts of Himachal Pradesh. Field investigations and understanding characters of failure by geotechnical investigation found to be key factor of deciding possible remedy and mitigation technique possible failure slope. Compression of different approach has shown that random forest approach provides more reliable result in Nahan to Rajgarh region where as information value approach more reliable at Chamba region in preparing landslide susceptibility zonation map. Use of geotechnical analysis software like Plaxis 2d is found highly effective to analyzing slops and effectivity of solution. Research has shown its application in analyzing Factor of safety, deformation and stresses development in slope as well as possible solution.

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