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Empirical Model for Landslides Susceptibility in the Himachal Pradesh

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ABSTRACT

Many natural and man-made hazards affect Himachal Pradesh in India. Even though there are various dangers in the state, landslides are the most common and occur most frequently during the rainy season. Existing research aims to understand the current state of knowledge in Himachal Pradesh about the management of landslide hazards. Landslide disasters in the state are well managed under the state's established policy. Landslide susceptibility zonation maps prepared using GIS have been shown to be the primary method of preventing landslides, while geotechnical investigations of soil have been found to aid in the determination of possible mitigation techniques. Software like Plaxis 2d is proven to be extremely useful in analysing slopes and the effectiveness of solutions.

Keywords-- Landslides Susceptibility, Geospatial Planning, Plaxis 2D, Method, Landslide Hazard Mapping

I. INTRODUCTION

Landslides have been increasing in the Himalayan mountain range over the past few years, but there has been little research into what causes them and how to prevent them. The state of hills in India is called Himachal Pradesh. Physiologically, it is separated into three zones. The Himalayas on the outskirts (Shivaliks) The Lesser Himalayas (central zone) A litho-tectonic setting for each range in the Great Himalayas (northern zone) varies from the Siwalik to the Lesser Himalayan. There are a variety of natural and anthropogenic hazards in the state, as described by state policy on disaster management. Landslides and dam failures are the primary dangers. All year round, however, the monsoon season is particularly dangerous for landslides. Landslide risk is growing due to causes such as increased rainfall, deforestation, and road building. Landslide deaths are most common along the Himalayan range and in China, according to Petley's research. Pre-disaster phases include prevention, mitigation, and readiness, whereas post-disaster phases include response, rehabilitation, and recovery. DM continuums typically have six aspects. All of these aspects are held together by a legal and institutional framework (Diagram 1).

Various components make up the Himachal Pradesh State Disaster Management Policy continuum. The disaster management cycle consists of a variety of components. Fig. 1 shows how this works. While some work is done on post-disaster studies of landslides, the bulk of the effort is focused on giving various landslide remedies and creating landslide susceptibility zonation maps. Today, GIS may be used in a variety of ways to help manage landslides, including direct and indirect approaches to assessing different maps of a region and creating a prediction map. Using the direct method, geomorphology can be utilised to map landslide hazards, while the indirect method relies on causative factors to assign varying values to various variables. Scientific literature is dominated by the use of indirect methods. Although the National Drought Mitigation Agency (NDMA) provides a national landslide zonation map, the state DM policy does not. Existing research aims to understand the current state of knowledge in Himachal Pradesh about the management of landslide hazards.

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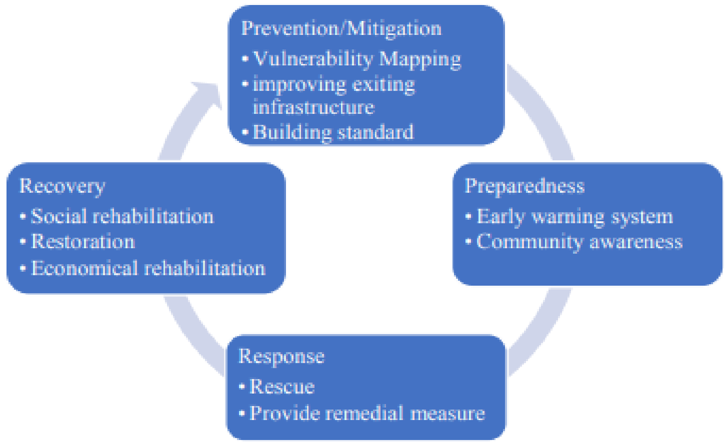

Figure 1: The disaster response cycle

II. LANDSLIDE SUSCEPTIBILITY ZONE

It is possible to spatially forecast a landslide's susceptibility by taking into account a variety of contributing elements. Landslides are generally predicted based on prior landslides and other probable circumstances, but this isn't always the case. Qualitative and quantitative landslide methodologies are the most common, but there are numerous more.

Figure 2: Himachal Pradesh is depicted on this Indian map.
Source: https://www.freeworldmaps.net/asia/india/himachalpradesh/

Landslide Susceptibility Zone in Himachal Pradesh

An information value approach was used to create the LSZ map of Dharmshala city. Site visits and GPS confirmed the locations of other landslides, which were observed and documented. The literature cites the information value approach as a method for drawing a map of a given area. They considered lithology, aspect, soil type, fault density, land cover, slope, and drainage density as possible causal factors in their investigation. ArcGIS software was used to visualise the pixel values of each landslide on a map of the surrounding area. An extensive set of data is gathered to determine what causes landslides

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in this part of the world. They've used ASTER GDEM with a 30m resolution and Google Earth pictures to map the land cover. They used ASTER GDEM and ESRI ArcGIS software to find the slope, aspect, and drainage network. Zoning for landslide susceptibility in the Dharamshala area is done using the information value (In V) approach. In order to determine the value of information, we count the number of pixels from various classes in each factor and the number of pixels from landslides in each class. The landslide susceptibility map is created by overlaying several map layers using ArcGIS software and the information value of each subclass. Susceptibility was classified as low, medium, high, or extremely high using a revised LSZ map with five distinct classes. A total of 0.65 square kilometres of the 0.66 square kilometres of landslides are classified as having very high susceptibility.

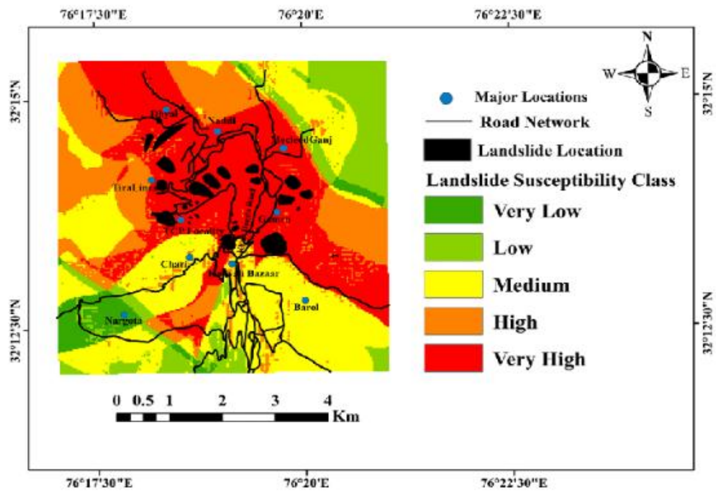

Figure 3: Map of the Dharamshala region's landslide susceptibility zone, which shows susceptibility levels: low, medium, high, and extremely high

The purpose of this analysis is to look at the causes of various landslides in the Himalayan region and assess the sedimentary properties of those landslides. In terms of topography, Himachal Pradesh is noted for having the Siwalik, the Lesser, and the Great Himalayan mountains in its backyard. In the course of this research, a route through the Siwalik and the Lesser Himalayan ranges was opted for. The Rajgarh-Nathan highway corridor was chosen for this study's route. Landslide features were first observed by making regular visits to the site. In their analysis, they found 34 landslides along the route. Different parameters, such as height, width, soil moisture, and land cover, were discovered. A greater number of small-scale landslides were found to occur. Debris flow, slide, fall, and rock slide were the most frequently witnessed phenomena. It was determined that slope was the primary cause of the highway landslide, whereas slope toward the river was caused by river undercutting. Additional geotechnical tests were performed on the two soil samples gathered from different locations to better understand the landslide's soil character. Grain size distribution, liquid limit, and in situ rock strength tests were performed. The lack of tiny particles in the area indicates high porosity, which allows rain water to easily seep through. Regular farming above the slope area is essential in order to raise the water content of the slope. Many cracks were found at location 2 that play a significant function. Slope steepness was another factor in the rock strength results, with a value of 15.3Mpa indicating a very low value of strength. A comparison of the results from various approaches to arrive at the best susceptibility zonation map was also carried out in this study. Different methods such as RF (random forest), BRT (boosted regression tree), SVM (support vector mechanism), and GLM (general linear model) are employed (Generalized Linear Model). A total of 12 factors were used in their study, including aspect, plan curvature, slope, profile curvature, stream buffer topographic wetness index, road buffer fault, type of soil, land use, land cover, lithology, and geology map. The highest success rates were found with an RF approach, which was verified by AUC with a 90% success rate.

The NH154A highway corridor, which runs from Bharmor to Chamba, was the site of this study's LSZ map development. The frequency ratio method and the information value method were both employed and compared. Slope, aspect, land use and land cover, soil type, curvature, lithology, relative relief, drainage density,

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and lineament density were some of the contributing elements to landslides that were examined in this study. Another map was acquired from several government departments while DEM was being used to extract slope, aspect, and curvature data. Phyllites and slates make up the majority of the land, while dark grey slate, micaceous sandstone, and quartzite lithology all contribute significantly to landslides. Six LULC classifications were also taken into consideration, with the majority of the land falling under barren land, all of which contribute significantly to landslides. A landslide's main contributor is loamy soil rather than the finer, more widely distributed coarse loam. There was also a noticeable difference in the perimeter.

Table 1: Each class in terms of information value and frequency ratio

Methods	**Value-added Information Method**		**The Frequency Ratio Method.**	
Hazard Zones	Area (%)	Area at Risk of Landslides (%)	Area (%)	Area at Risk of Landslides (%)
Very low	15.4	1.5	29.96	2.54
Low	29.99	9.41	25.51	15.32
Medium	26.93	16.00	13.16	8.91
High	15.75	23.22	17.28	18.18
Very High	11.93	49.87	14.09	55.05

The information value method has a better prediction rate of 78.87 percent based on AUC results than the frequency ratio method, which has a prediction rate of 75.37 percent.

Figure 4: Kullu's landslide susceptibility zone

Source: https://citeseerx.ist.psu.edu/viewdoc/download

By employing multivariate criteria analysis, a landslide danger map for the Kullu district of Himachal Pradesh was generated. This was done using images from the LANDSAT ETM+ and the IRS P6 satellites in order to derive land use data at a 15-meter resolution. Using DEM data from the ASTER satellite, parameters such as aspect, drainage density, and slope were retrieved. Landslide locations were drawn on GIS using GPS coordinates from field visits. The geological map of the area is used to study the area's lithology. Slope, aspect, relief, physiography, lithology, drainage density, and land use were all used as causal factors in the study. In total, 49 landslides were taken into account in his research. The final Kullu LSZ map depicts a 0.42 percent zero risk zone, a 19.42 percent low to moderate risk zone, a 48.16 percent high risk zone, and a 32.00 percent extremely high to severe danger zone.

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Nearly all of Kullu falls within a "high to severe" landslide risk zone, indicating a significant need for landslide prevention and remediation measures.

III. THE MITIGATION OF LANDSLIDES

For landslide prevention, a mix of solutions is typically used. This requires field inquiry and an awareness of both the causative and trigging factors at the site. A better understanding of how a landslide occurs can help engineers choose the best feasible repair and preventative measures for a risky slope. Many authors categorise solutions into four categories, including changes in slope geometry, drainage, retaining structures, and internal slope reinforcement.

Atterberg's limit, triaxial test, chemical analysis, compaction test, grain size analysis, and direct shear are among the geotechnical tests that were performed on 27 samples collected from the Kotropi landslide site in 2017 in the first part of the investigation. The soil was classed as SP-SM. Chemical tests were also conducted to determine the long-term safety of the nail, as PH greater than 7 is not suggested in terms of nail safety. When the PH value of soil was researched, it revealed values as low as 6.5 and up to a maximum of 7, which was considered safe. The more torque-oriented installation of a helical soil nail was chosen over a conventional nail because of the higher levels of vibration that occur during driving and installation of a conventional nail. The length of a nail's fin was determined to be 6 metres and the angle of its inclination to be 15 degrees. The overall slide height was 30 m, but it was divided into 10 m sections for greater safety. In both the vertical and horizontal directions, nails were spaced 1 metre apart. After stabilisation, a numerical model of the slope was created in Plaxis 2d software to examine the new factor of safety. The axial stiffness and bending stiffness of the nail were calculated in further detail. a factor that can be utilised in the creation of models. The stiffness values for the axial and bending stiffness of the nail were both 0.06280 x 9 x 10-3 KN/m. The soil nail's safety, deformation, and stress were the most important factors to investigate. Deformation decreased from 0.13m to 0.06m as a result of an increase in FOS from less than one in the initial slope. There was no evidence that the nail had come into contact with the failure surface.

Figure 6: Image of the site of the landslide at Kotrupi in Himachal Pradesh
Source: https://blogs.agu.org/landslideblog/2017/08/13/kotrupi-1/

IV. CONCLUSION

The goal of this review was to determine the current state of knowledge on landslide management in Himachal Pradesh. No effort is observed in terms of various prevention/mitigation techniques like Vulnerability Mapping in terms of preparedness like an early warning system response by providing corrective measures, while the state has established policies for controlling landslide disasters in the state. The use of GIS software to create a landslide susceptibility zone map has proven to be a highly successful option for numerous stakeholders, decision makers, and engineers when making decisions like where to build, where to route new roadways, and how to ensure proper traffic flow. Many districts in Himachal Pradesh lack a landslide susceptibility map. Geotechnical investigations were shown to be a critical aspect in determining feasible remedies and mitigation techniques for possible failure slopes. In producing landslide susceptibility zonation maps, compression of multiple

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approaches has revealed that the random forest strategy produces more trustworthy results in the Nahan to Rajgarh region than the information value approach does in the Chamba region. Software like Plaxis 2D is found to be quite useful in analysing landslides and the efficacy of their solutions. Slope safety, deformation, and stress growth can be analysed using this method, as can viable solutions.

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