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Analysis of Himachal Pradesh's Landslides Hazard Management

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ABSTRACT
A variety of natural and man-made risks have an impact on Himachal Pradesh in India. Despite the state's many potential hazards, landslides are the most frequent and tend to happen more frequently during the rainy season. The goal of this research is to comprehend the level of knowledge regarding landslide hazard management in Himachal Pradesh at the moment. Under the state's established strategy, landslide disasters are effectively managed in the state. Geotechnical investigations of the soil have been shown to be helpful in figuring out possible mitigation strategies. Using GIS to make landslide susceptibility zonation maps has been shown to be the best way to stop landslides. It has been demonstrated that tools like Plaxis 2D are quite helpful for analyzing slopes and the efficacy of solutions.

Keywords: *landslides, pixel values, susceptibility, mapping, reinforcement*

I. INTRODUCTION

Over the past few years, the number of landslides in the Himalayan mountain range has increased, yet little is known about their causes or ways to prevent them. In India, the state of the hills is known as Himachal Pradesh. The body is divided into three zones physiologically. The Shivaliks, which are part of the Himalayas, The central region of the smaller Himalayas Each range in the Great Himalayas (northern zone) has a unique litho-tectonic setting, ranging from the Siwalik to the Lesser Himalayan. The state's disaster management policy lists a variety of natural and man-made dangers throughout the state. The main risks are dam collapses and landslides. However, the monsoon season is when landslides are most risky throughout the year. Due to factors including increased rainfall, deforestation, and road construction, the risk of landslides is rising. According to Petley's research, China and the Himalayan range have the highest number of landslide fatalities. Stages before a disaster include preparation, mitigation, and prevention, whereas stages after a disaster include reaction, recovery, and rehabilitation. Six features are commonly present in DM continuums. A framework of laws and institutions holds all of these components together (Diagram 1). The continuity of the Himachal Pradesh State Disaster Management Policy is made up of various elements. There are many different parts to the disaster management cycle. This is illustrated in Fig. 1. The majority of the effort is concentrated on providing several landslide cures and developing landslide susceptibility zonation maps; however, some work is done on post-disaster investigations of landslides. Today, there are numerous ways to utilize GIS to aid in managing landslides, including direct and indirect methods of evaluating various maps of a region and producing a forecast map. Geomorphology can be used to map landslide dangers using the direct technique, whereas the indirect method depends on causative factors to give different values to various variables. Indirect approaches are often used in scientific publications. The state DM strategy does not include a national landslide zonation map, despite the fact that the National Drought Mitigation Agency (NDMA) does. The goal of this research is to comprehend the level of knowledge regarding landslide hazard management in Himachal Pradesh at the moment.

II. ZONE SUSCEPTIBLE TO LANDSLIDE

A landslide's vulnerability can be geographically predicted by considering a number of contributing factors. Although this is usually the case, not all landslides can be predicted based on past landslides and other likely circumstances. The most commonly used landslide approaches are qualitative and quantitative, but there are many more.

2.1 Himachal Pradesh's Zone of Susceptibility to Landslides

The LSZ map of Dharmshala city was produced utilizing an information value technique. Site inspections and GPS data supported the locations of other landslides that were seen and recorded. The information value technique is mentioned in the literature as a way to map out a specific area. In their analysis, they looked at lithology, aspect, soil type, fault density, land cover, slope, and drainage density as potential causes.

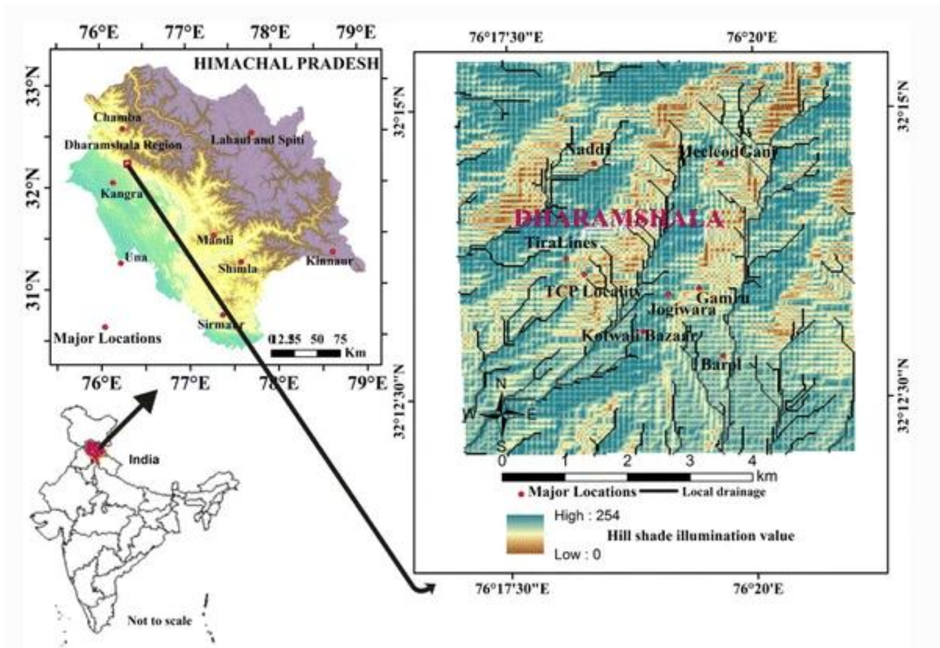

Figure 1: Map of the Dharamshala region's landslide susceptibility zone

The pixel values of each landslide were displayed on a map of the surrounding area using ArcGIS software. In order to ascertain what triggers landslides in this region of the world, a vast amount of data is acquired. In order to map the land cover, they employed Google Earth images and ASTER GDEM with a 30m resolution. The slope, aspect, and drainage network were located using the ASTER GDEM and ESRI ArcGIS software. In the Dharamshala region, zoning for landslide susceptibility is done using the information value (InV) approach. We count the number of pixels from various classes in each factor as well as the number of pixels from landslides in each class to ascertain the worth of the information. Using ArcGIS software and the information value of each subclass, various map layers are overlaid to build the landslide susceptibility map. A redesigned LSZ map with five unique classes was used to categorize susceptibility as low, medium, high, or extremely high. Of the 0.66 square kilometres of landslides, 0.65 square kilometres are categorized as having very high susceptibility.

This analysis's goals are to determine the origins of various landslides in the Himalayan region and evaluate their sedimentary characteristics. Himachal Pradesh is renowned for its terrain, which includes the Siwalik, Lesser, and Great Himalayan Mountains. The Siwalik and Lesser Himalayan ranges were chosen as the route for this research. The highway corridor between Rajgarh and Nathan was picked as the study's path. Regular site visits allowed for the initial detection of slides' physical characteristics. In the course of their investigation, they discovered 34 landslides. There were found to be several criteria, including height, width, soil moisture, and land cover. There were more small-scale landslides than previously thought. The most common phenomena were rock slides, debris slides, and falls. According to research, slope toward the river was primarily responsible for slope toward the highway. Two soil samples collected from various sites were subjected to additional geotechnical testing in order to better understand the soil nature of the landslide. It was tested for grain size distribution, liquid limit, and in situ rock strength. The absence of microscopic particles in the area suggests great porosity, which makes it easy for rainwater to permeate. To increase the water content of the slope, regular farming is required above the slope area. At position 2, a substantial number of cracks were discovered. Another element that affected the rock strength findings was slope steepness, with a value of 15.3 MPa indicating relatively low strength. This study also included a comparison of the outcomes from several ways to determine the optimal susceptibility zonation map. It uses a variety of techniques, including RF (random forest), BRT (boosted regression tree), SVM (support vector mechanism), and GLM (general linear model). They included aspect, plan curvature, slope, profile curvature, stream buffer topographic moisture index, road buffer fault, type of soil, land use, land cover, lithology, and geology map in their analysis of a total of 12 variables. The RF method had the highest success rates, which were supported by AUC's 90% success rate.

The LSZ map for this study was created for the NH154A highway corridor, which connects Bharmor and Chamba. Both the information value approach and the frequency ratio method were used and contrasted. Some of the factors that contributed to landslides were looked at in this study, including slope, aspect, land use and land cover, soil type, curvature, lithology, relative relief, drainage density, and lineament density. While using DEM to extract slope, aspect, and curvature data, another map was obtained from various government agencies. The majority of the land is composed of phyllites and slates, while quartzite lithology, dark grey slate, and micaceous sandstone all significantly contribute to landslides. Additionally, six LULC classifications—all of which significantly contribute to landslides—were taken into account, with barren land accounting for the majority of the land. Loamy soil, as opposed to the finer, more widely dispersed coarse loam, is the principal cause of landslides. The perimeter had also changed, which was apparent.

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

A landslide threat map for the Kullu district of Himachal Pradesh was created using multivariate criterion analysis. Land use data with a 15-meter resolution was obtained using photos from the LANDSAT ETM+ and IRS P6 satellites. Aspect, drainage density, and slope were among the metrics that were obtained using DEM information from the ASTER satellite. Using GPS data from on-site visits, land slide spots were depicted on a GIS. The lithology of the region is investigated using the area's geological map. The study employed a variety of causal factors, including slope, aspect, relief, physiography, lithology, drainage density, and land use. In total, 49 landslides were considered in his study. 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 are all shown on the final Kullu LSZ map. Nearly all of Kullu sits within a "high to severe" landslide risk zone, indicating a major need for landslide prevention and remediation measures.

III. THE MITIGATION OF LANDSLIDES

For landslide prevention, a variety of solutions are often used. This calls for on-site investigation and awareness of both the causal and trigging elements. A deeper understanding of how a landslide happens might help engineers determine the most viable repair and prevention measures for a dangerous slope.

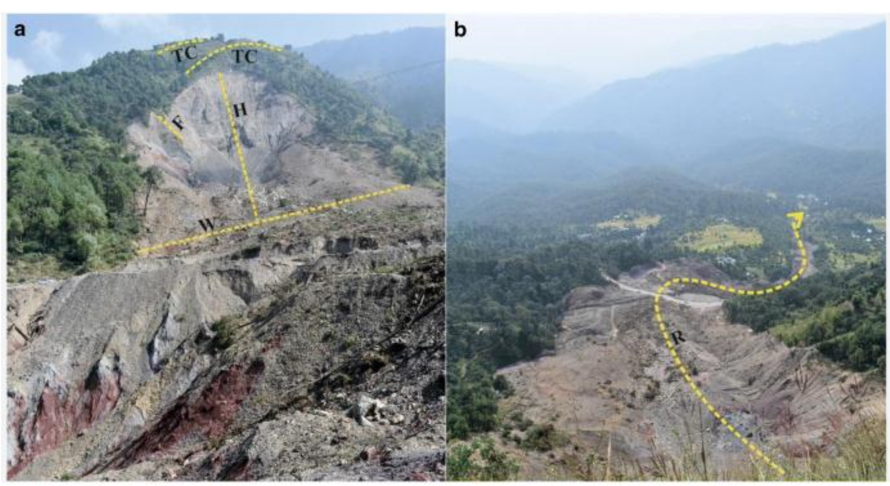

Figure 2: Image of the site of the landslide at Kotrupi in Himachal Pradesh

Many authors divide solutions into four categories, including changes in slope geometry, drainage, retaining structures, and internal slope reinforcement.

In the first phase of the inquiry, 27 samples were taken from the Kotropi landslide site in 2017 and subjected to a variety of geotechnical tests, including Atterberg's limit, triaxial test, chemical analysis, compaction test, particle size analysis, and direct shear. SP-SM was assigned to the soil. Chemical tests were also carried out to verify the nail's long-term safety because PH values greater than 7 are not advised for nail safety. When the PH value of the soil was examined, it indicated levels as low as 6.5 and up to a maximum of 7, which was regarded as safe. Due to the higher levels of vibration that happen during the driving and installation of a conventional nail, the more torque-oriented installation of a helical soil nail was preferred. The length of a nail's fin was measured at 6 meters, and its inclination was found to be 15 degrees. The slide's overall height was 30 m, but for added safety, it was broken into 10 m parts. Nails were placed 1 meter apart in both the vertical and horizontal axes. Following stabilization, a numerical model of the slope was built using the Plaxis 2D program to analyze the new safety factor. Further calculations were made to determine the nail's axial stiffness and bending stiffness, a variable that can be used in the development of models. Both the axial and bending stiffness values for the nail were 0.06280 x 9 x 10-3 KN/m. The most crucial aspects to look into were the safety, deformation, and stress of the soil nail. As FOS increased from less than one on the first slope, deformation decreased from 0.13m to 0.06m. No indication that the nail had made contact with the failure surface could be found.

IV. CONCLUSION

Finding out the state of knowledge on landslide management in Himachal Pradesh was the main objective of this review. While the state has created regulations for managing landslide catastrophes in the state, no effort is seen in terms of various prevention and mitigation approaches like vulnerability mapping in terms of readiness, like an early warning system responding by giving corrective measures. When making decisions on where to develop, where to route new roadways, and how to maintain adequate traffic flow, many stakeholders, decision-makers, and engineers have found great success in using GIS software to create a map of the landslide susceptibility zones. In several of Himachal Pradesh's districts, there is no map showing the likelihood of landslides. The importance of geotechnical investigations in identifying workable solutions and mitigation strategies for potential failure slopes was demonstrated. Multiple methods have been used to make maps of where landslides are likely to happen. The results show that the random forest strategy gives more reliable results in the Nahan to Rajgarh region than the information value approach does in the Chamba region. It has been discovered that software like Plaxis 2D is highly helpful in analyzing landslides and the effectiveness of their solutions. Using this approach, it is possible to analyze slope safety, deformation, stress buildup, and workable solutions.

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