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LANDSLIDE PREDICTION AND HAZARD ZONATION USING GEO-SPATIAL TECHNOLOGY

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ABSTRACT

Landslides are one of the most damaging disastrous phenomena that frequently lead to serious problems in hilly area. It poses significant risks to human lives and infrastructure, making accurate prediction and hazard zonation crucial for mitigating their impacts. This paper proposes a geospatial technology-based method utilizing the Analytical Hierarchy Process (AHP) for landslides prediction and hazard zonation.

The methodology involves the integration of various geospatial datasets, including topography, geological features, land cover, rainfall patterns, slopes, aspects, and lithology, Fault, Road, and Stream Data. These datasets are processed and analyzed using the AHP technique, which provides a systematic approach for determining the relative importance and weights of different factors influencing landslide occurrence.

The AHP methodology involves the construction of a hierarchical structure, with the landslide susceptibility and hazard as the main criteria. Sub-criteria, such as slope gradient, lithology, land cover, rainfall intensity, and land use, are identified and weighted based on their influence on landslide occurrence.
To validate the model, historical landslide occurrences are collected, and their spatial relationships with the identified factors are analyzed. The AHP model is then calibrated and validated using these landslide occurrences, providing a robust prediction and hazard zonation framework.

The results of the study demonstrate the effectiveness of the proposed methodology in predicting landslide occurrences and identifying hazard zones. The geospatial technology-based approach combined with the AHP technique offers a comprehensive and objective analysis, considering various contributing factors simultaneously.

Keywords: Landslides, prediction, hazard zonation, geospatial technology, Analytical Hierarchy Process (AHP), landslide susceptibility, decision-making, risk mitigation.

INTRODUCTION

A landslide is the mass movement of rock, soil, and debris down a slope due to gravity. It occurs when the driving force is greater than the resisting force. It is a natural process that occurs in steep slopes. The movement may range from very slow to rapid. It can affect areas both near and far from the source. Also known as landslips, are several forms of mass wasting that may include a wide range of ground movements, such as rock falls , deep-seated slope failures, mudflows, and debris flows. Landslides occur in a variety of environments, characterized by either steep or gentle slope gradients, from mountain ranges to coastal cliffs or even underwater. (Landslides National Hazards and Disasters, Department of Institutional Development National Institute of Education 2008).

In which case they are called submarine landslides. Gravity is the primary driving force for a landslide to occur, but there are other factors affecting slope stability that produce specific conditions that make a slope prone to failure.

In many cases, the landslide is triggered by a specific event (such as a heavy rainfall, an earthquake, a slope cut to build a road, and many others), although this is not always identifiable. Landslide frequently occurs in mountain terrain. As the

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rock has been breaking up and decomposed during the weathering process, the material that is weathered is soaked with water or rain which may lead the slide down because of gravity. This sudden downward slide of rock debris is known as landslide condition. On any terrain, a landslide occurs in the presence of the right environment of moisture, soil, and slope angle. Alongside regular states of topography surface of the earth, the avalanches help to dregs and redistribute soil in a procedure that can be in sudden falls or moderate mudflows. They can occur in any environment where there is sufficient slope to cause material to move downhill, including mountain slopes, coastal cliffs, and even urban settings. As climate change continues to increase the frequency and intensity of extreme weather events, the risk of landslides is increasing. Therefore, it is important to understand the causes of landslides and to develop effective strategies to reduce the risk they pose. (Landslides National Hazards and Disasters, Department of Institutional Development National Institute of Education 2008).

LITERATURE SURVEY

Lee and Pradhan (2016), combined frequency ratio and logistic regression model for mapping the 13 landslide susceptible areas by considering slope, aspect, curvature, distance from drainage, 14 lithology, and distance from lineaments, land cover, vegetation index, and precipitation as 15 landslide stimulating factors. They calculated the Landslide Hazard Index (LHI) by summa- 16 tion of frequency ratios for all the factors and solving the regression equation, respectively, for 17 both methods and concluded that the frequency ratio model has 2.7% (93.04–90.34%) better 18 predication accuracy than the logistic regression model.

Pradhan et al (2016), they used frequency ratio and fuzzy algorithm for generating landslide 20 hazard maps. Fuzzy membership values were calculated using frequency ratio and detected 21 landslides. Fuzzy algebraic operators (such as fuzzy and, or, product, sum) and fuzzy gamma 22 operators were applied on fuzzy membership values for landslide hazard mapping. Value of 23 fuzzy gamma operator was set to 0.025, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95, and 0.975 24 for detecting its effect on landslide hazard maps. After verification, they found that out of 17 25 cases tested, the gamma operator with value 0.8 performed best (prediction accuracy 80.26%), 26 while 'Fuzzy algebraic sum' and 'fuzzy or' showed worst accuracy of 64.77% and 56.86%, 27 respectively.

Dinesh Pathak (2016), He studied the Remote sensing and GIS application in landslide risk assessment and Management he prepared a landslide hazard map to minimize the risk involved in development schemes for mitigation and control measures monitor change in land use and core patterns and landslide occurrence .He showed the remote sensing data contribute in various related to natural resources management including landslide disaster management the spectrum of satellite sensors with large swat and very special resolutions are valuable for remote sensing application with the help of GIS and remote sensing data he prepared landslide inventory map and classified hazard map mitigation at the source area.

Amit Bera et al (2019), developed landslide hazards zonation mapping using multi criteria analysis with the help of GIS techniques and prepared a case study from eastern Himalayas Namchi South Sikkim. They prepared various thematic layers namely slope rainfall distribution map lineman density drainage density slope aspect geology and use land cover and soil map and integrated in GIS platform using (ArcGIS) 10.1 .They use Analytical Hierarchy Process to determine the weight values of different factors the landslide hazards donation map of namchi region was produced based on weighted only technique it is divided into five Vulnerable Zones like(very low, low, moderate, high and very high) hazards zones .The final landslide hazards zonation map can be used to landslide hazard prevention proper planning of future investigation and Geo-environmental development in the namchi region.

Shantanu Sarkar et al (2006), used traditional techniques for landslide susceptibility mapping in case study in Indian Himalayas. They prepared important causative factors for landslide and prepared thematic data layer in GIS. They prepared data from topographic map, satellite image, satellite image, and field data and published maps and they use numerical weights for different categories, for this factors were determine in statistical approach and then integrated in GIS environment to arrive land susceptibility mapping of area. They classified area into five classes such as (very high, high, moderate, low and very low). The study was attempted to validate map with the existing landslide of areas.

Wang Jian et al (2009), presents GIS based landslide hazard zonation model and its application. They carried out study with the help of remote sensing and GIS technologies, data layers preparation buffer map of thrust, lithology, slope angle, relative relief NDVI, and drainage lineaments for analysis of landslide hazard zonation. All the data according to weights rated value of various data layers the landslide hazard index is calculated and statistical analysis of histogram is given. Landslide deformation control point are applied to verify the landslide hazard zonation results. The distribution of control point it's are overlapped in landslide hazard map and the statistics show there is no landslide on High stable slope zone and only 3% of landslide control points on stable slope zone (account for 14.02% of all the area). Quasi-stable slope zone,

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relatively unstable slope zone and unstable slope zone include 31%, 34% and 18% landslide control points respectively. Up to 15% of the landslide control points are located on defended slope zone only account for 3.47% of all the area. Main landslide control points locates between quasi-stable slope zone and relatively unstable slope zone, which has 65% landslide control points. Landslide control points in unstable slope zone and Defended slope zone area are 33%. Landslide hazard may happen once meeting with heavy hazard condition such as strong flood.

Roessner et.al. (2000) used Remote Sensing and GIS for landslides risk assessment. They combined the analysis of multispectral satellite data, DEM (Digital Elevation Model) and geological information and they mentioned that there is a lack of geographic information available in Kazakhstan and that affect to the accuracy of their study. They compared between different types of Remote Sensing tools which are available and conclude that it is important to use satellite remote sensing for improving landslide hazard assessment.

Ramakrishnan et.al. 2002, developed a TIN (Triangular Irregular Network) model in order to generate the landslide susceptibility map in a GIS environment by using the Arc view 3D analysis; this model was created from the digitized contour map to measure the effect of the causative factors in the landslide prone areas. Four factors were considered for this study. Overlay analysis has been done for weighting. The weight assignment was prepared in a LUT (look up table) and linked with union coverage. A ground validation was done by the derived landslide map. They conclude that success in landslide management can be achieved with a full and comprehensive knowledge of some basic factors including character and magnitude of the mass movement in an area.

Feizizadeh et.al. (2011), combined both of GIS and Rem2.ote sensing for landslide hazard susceptibility thematic map, through applying fuzzy logic model; they have been involved 7 factors to conduct this study. They gave each factors weight based on using an AHP method. the overall accuracy and the kappa coefficient for this study were 90.2% and 0.88 respectively, it reflects that following this methodology will give high accuracy, however, there is no verification method to follow, in order to test and examine the derived accuracy for this study, the author very satisfied with the weighted values from AHP for each factor that contributed in processing and analyzing in this study, also mapping the landslide hazard with 7 factors even with using powerful approach like fuzzy logic model will not reach high accuracy, we suggest increase the number of factor to at least ten factor to derive satisfactory accuracy.

Derricks P. Shukla et.al. (2016), study different methods for landslide prediction and hazard zonation using geospatial technology. There are various methods for the preparation of LSZ maps such as based on Fuzzy logic, Artificial Neural Network, Discriminant Analysis, Direct Mapping, Regression Analysis, Neuro-Fuzzy approach and other techniques. These different approaches apply different rating system and the weights, which are area and factors dependent and vital role in preparation of susceptibility maps.

OBJECTIVE

1. Prediction of landslide regions in haridwar and devprayag region in uttarakhand .
2. Preparation of landslide hazard zonation mapping to indicate the landslide prone areas
3. Use AHP method to find weights of the triggering factors .
4. To find out the the triggering factors in QGIS softwares.

INPUT DATABASE

We performed different types of Maps by Geo-Spatial Technique.

1. **DEM MAP**

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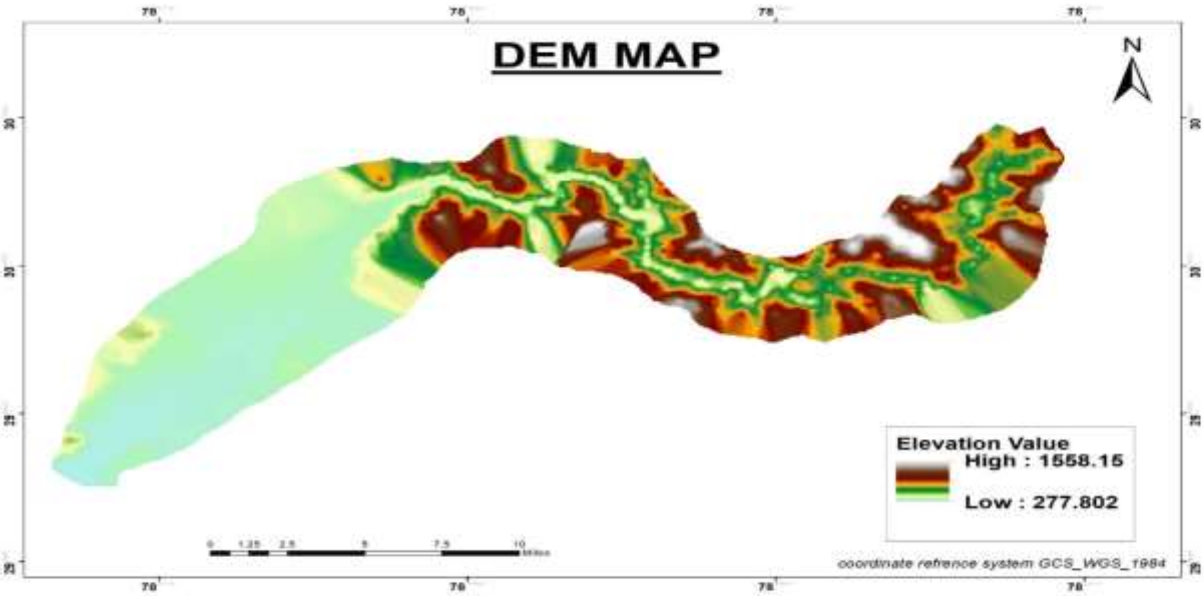
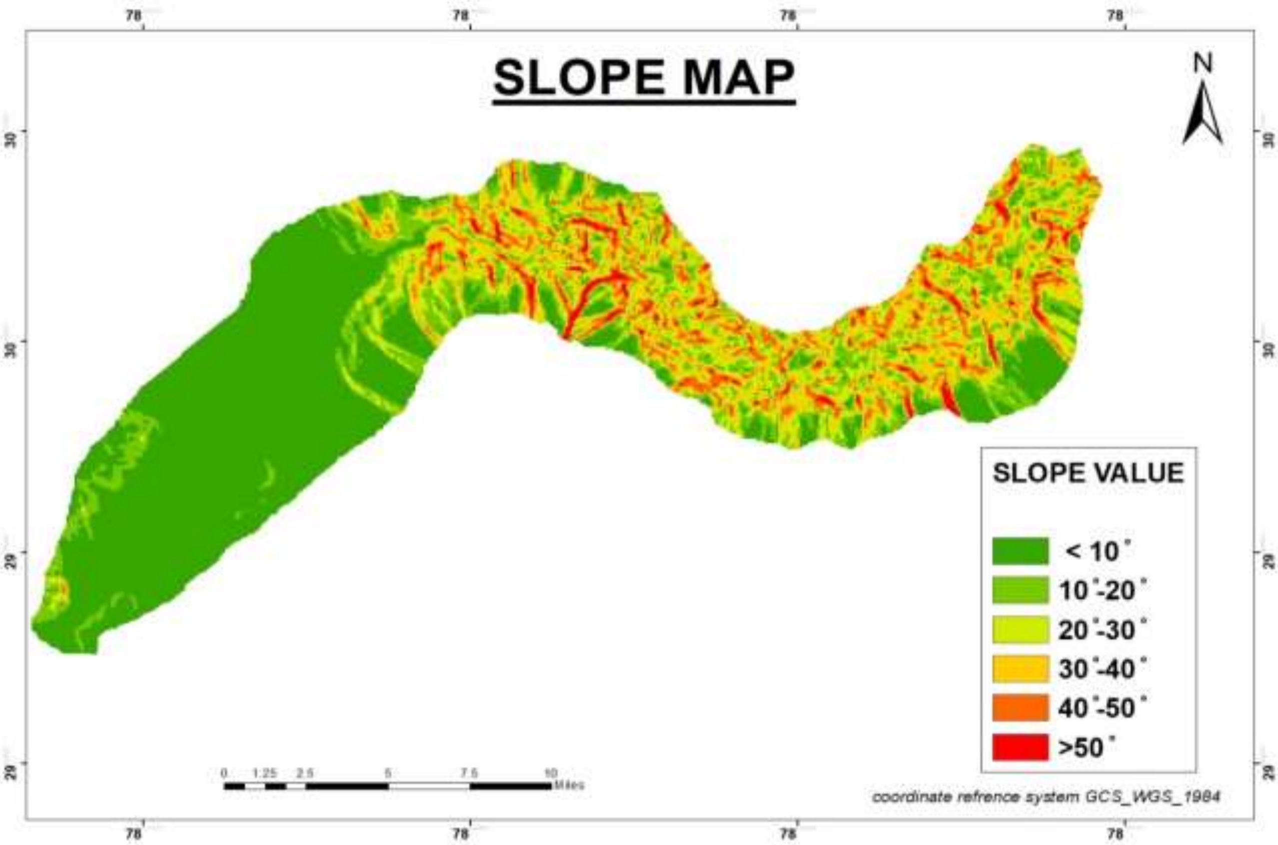


2. SLOPE MAP



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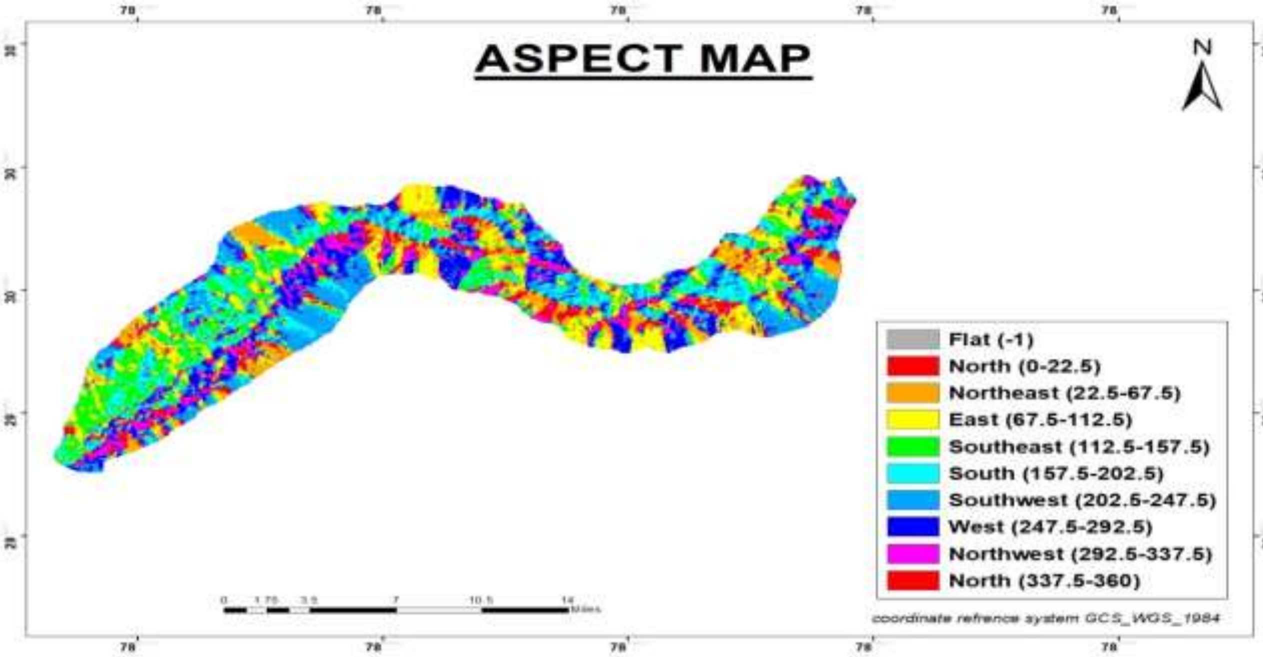
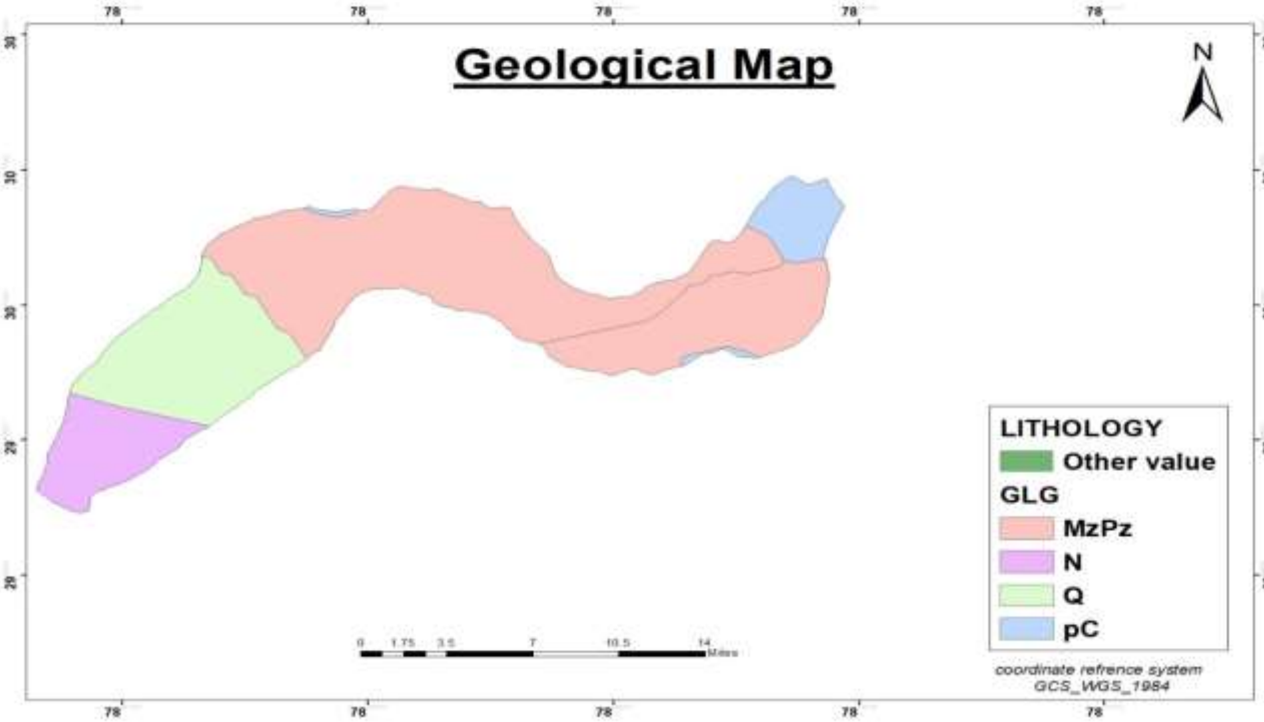
3. ASPECT MAP



4. **Geological map**



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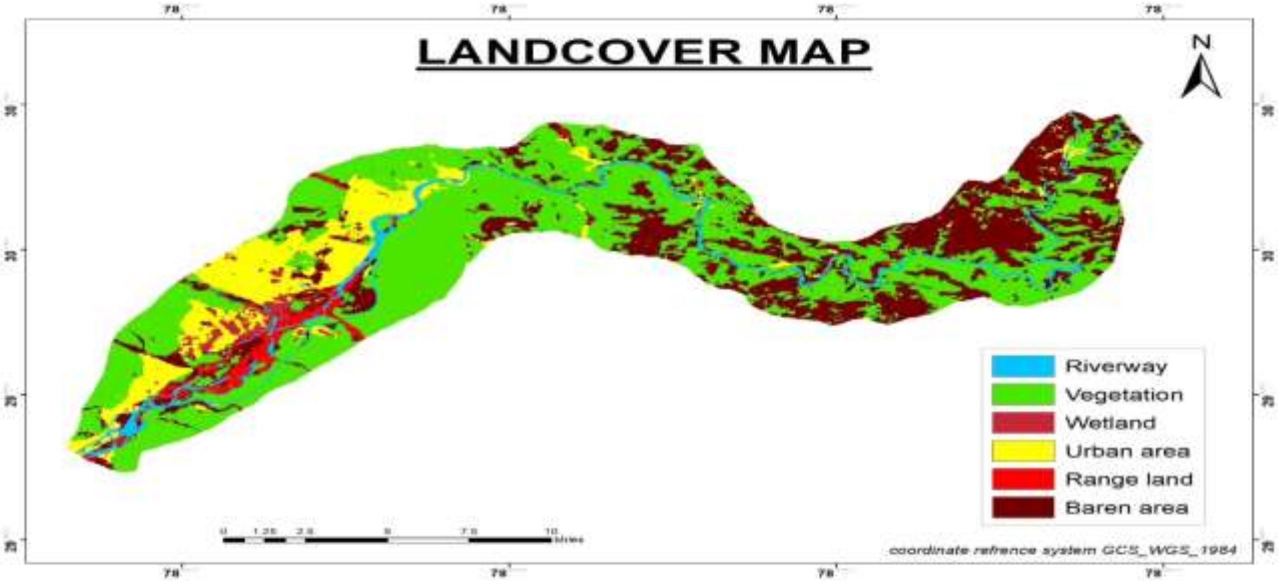
5. **Land cover Map**



APPLICATION

Landslide prediction and hazard zonation mapping using geospatial technology have proven to be valuable tools in mitigating the risks associated with landslides. Here are some important applications of this approach:

Early Warning Systems: Geospatial technology enables the monitoring and prediction of landslide occurrences by integrating various data sources such as satellite imagery, weather data, and ground-based sensors. By analyzing these data, scientists and authorities can identify potential landslide-prone areas and issue timely warnings to local communities, helping to minimize the loss of life and property.

Hazard Zonation Mapping: Geospatial technology allows for the creation of accurate and detailed hazard zonation maps, which provide a spatial representation of landslide susceptibility and risk. These maps consider factors such as slope gradient, geology, soil characteristics, land use, and rainfall patterns. By identifying high-risk zones, land planners, policymakers, and emergency management agencies can make informed decisions regarding land development, infrastructure planning, and evacuation strategies.

Land Use Planning: Geospatial technology assists in assessing the suitability of land for various activities and guiding land use planning. By incorporating landslide susceptibility maps into land use planning processes, authorities can avoid developing critical infrastructure, settlements, or agricultural activities in areas prone to landslides. This helps to reduce vulnerability and potential damage to human lives and infrastructure.

Natural Resource Management: Geospatial technology facilitates the identification and management of natural resources in landslide-prone areas. By mapping landslide hazards, authorities can implement appropriate measures to protect forests, watersheds, and other natural resources from degradation caused by landslides. This ensures sustainable resource management practices and helps maintain ecosystem services.

Emergency Response and Preparedness: Geospatial technology enhances emergency response and preparedness by providing real-time information during landslide events. Satellite imagery, remote sensing, and drones can capture high-resolution images of affected areas, helping emergency responders assess the extent of damage, identify affected infrastructure, and plan rescue operations. Geospatial data can also support logistical planning, resource allocation, and post-disaster recovery efforts.

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CONCLUSION

Haridwar devprayag band in the Uttarakhand state in India is bounded by UP in the west, Nepal in the east and Himachal Pradesh in the north. The present study is focused in the region of Ganga river band between Haridwar to Devprayag, which lies between the 29.9457N–78.1642E and 30.1459N, 78.5993E and covers an area of about 89km^2 is susceptible to frequent landslide occurrences and most common triggering factors for the landslide of this area are earthquake and heavy rainfall. In the present study, landslide hazard zonation mapping has been carried out using multi-criteria analysis (AHP-weighted) with the help of remote sensing and GIS techniques. This method is an effective tool to delineate vulnerable zone of landslide in a vast area where earlier records of landslides are less accessible. The landslide hazard zonation map divides the area into five different zones of susceptibility classes. The result was further validated through post-Feld survey with ground checks and also on the basis of landslide inventory. However, the prediction accuracy of the landslide hazard zonation map can be further improved by incorporating more factors. Further, any change in natural landscape by natural calamity and human interference, such as earthquake, deforestation and constructional work, may change the existing landslide vulnerability of the area. Hence, such hazard zonation maps should be updated periodically. The resulting landslide hazard zonation map of Haridwar to Devprayag region can be used as base data to support land-use planning and managing the slope in this region.

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