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Landslide Monitoring and Risk Assessment using GIS

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ABSTRACT:

Landslides are among the most destructive natural disasters, causing significant damage to infrastructure, property, and human lives, particularly in regions with unstable slopes. This research focuses on the Kethikal region of Vamanjoor, Mangalore, a landslide-prone area due to its geological and climatic conditions. The study aims to establish a comprehensive landslide monitoring and risk assessment system using Geographic Information System (GIS) technology.

The methodology integrates geospatial data with on-site investigations to identify high-risk zones and analyze contributing factors such as slope stability, soil composition, land use patterns, and hydrological conditions. GIS tools are employed for data analysis, producing hazard maps and risk assessment models. The findings underscore the effectiveness of GIS in accurately detecting and evaluating landslide hazards. Additionally, the study proposes mitigation strategies, including drainage system improvements, land use regulations, and slope reinforcements.

Keywords: Landslide monitoring, GIS technology, risk assessment, hazard mapping, slope stability, geospatial analysis, disaster prevention.

Introduction:

Landslides pose severe threats in regions with steep slopes and weak soil stability. Geographic Information Systems (GIS) offer a powerful framework for analyzing and predicting landslide risks by integrating spatial datasets, allowing for better hazard management. The occurrence of landslides is influenced by several factors, including geological formations, land use practices, and climatic conditions. Understanding these factors is essential for formulating effective preventive measures and minimizing damage. The complexity of landslide behavior necessitates a multidimensional approach involving field investigations, laboratory testing, and advanced geospatial analysis. GIS technology enhances the ability to map vulnerable areas, model hazard scenarios, and design targeted interventions based on scientific assessments.

GIS is particularly valuable in landslide-prone regions as it enables researchers to incorporate diverse data sources, such as satellite imagery, digital elevation models, and hydrological data, into a comprehensive framework. This integration provides a deeper understanding of terrain instability and helps predict future occurrences with greater accuracy. The use of GIS-based hazard mapping has been widely adopted in recent years, allowing authorities to make informed decisions for land-use planning, infrastructure development, and emergency response strategies.

The study area, Kethikal in Vamanjoor, Mangalore, experiences frequent landslides due to its high precipitation levels, steep slopes, and soil composition. The region's vulnerability necessitates an in-depth analysis of environmental and geotechnical parameters to develop effective mitigation strategies. The objective of this research is to assess landslide susceptibility using GIS, generate risk maps, and propose mitigation techniques that can be implemented by policymakers and urban planners. Through a combination of fieldwork, laboratory testing, and geospatial analysis, this study aims to provide valuable insights into the challenges and solutions associated with landslide risk management in the region.

Methodology:

1 Field Surveys

A detailed field survey was conducted in the Kethikal region to collect essential geotechnical data. Soil samples were collected from different elevations and tested for specific gravity, grain size distribution, and shear strength. Additionally, precipitation data was analyzed to determine its correlation with past landslide events.

2 GIS-Based Mapping

GIS software was used to generate hazard maps incorporating elevation models, slope gradients, and hydrological influences. The data was overlaid with past landslide locations to identify high-risk zones. Slope stability analysis was performed using digital elevation models.

3 Data Processing and Analysis

Survey data was processed using QGIS and AutoCAD, with contour maps and slope stability models generated for enhanced visualization. A triangulated irregular network (TIN) was created to evaluate terrain variations and slope inclination.

4 Factor of Safety Calculation

The stability of the slopes was analyzed using the Factor of Safety (FoS) method. The calculated values indicated that the top layer had the lowest stability, making it the most vulnerable to failure.

Results :

Test Results and Analysis

Specific Gravity Test

The specific gravity values for the collected soil samples ranged from 1.89 to 2.02. These values indicate that the soil is relatively loose and prone to erosion, influencing landslide susceptibility.

Grain Size Distribution

Sieve analysis revealed that the soil consists mainly of fine to medium particles. The uniformity coefficient (Cu) and coefficient of gradation (Cc) were calculated to assess soil permeability and compaction characteristics.

Liquid Limit and Plastic Limit

The liquid limit and plastic limit tests were conducted to determine soil consistency and plasticity. The results indicated that the soil exhibits moderate plasticity, which influences slope stability.

Compaction Characteristics

The Standard Proctor test was performed to determine the optimum moisture content (OMC) and maximum dry density (MDD) of the soil. The test results indicate that proper compaction is necessary to improve slope stability.

Permeability Test

The permeability test assessed the ability of water to flow through the soil. Results suggest that the soil has moderate permeability, which affects drainage and slope stability.

Shear Strength Analysis

Direct shear tests were performed to measure the cohesion (C) and angle of internal friction (Φ) of the soil. The results indicated that the topsoil layer had the lowest shear strength, making it highly susceptible to movement under stress.

Factor of Safety Results

The calculated FoS values for different soil layers were:

Top Layer: 1.12 (Highly unstable)

Middle Layer: 1.2 (Moderately stable)

Bottom Layer: 1.3 (More stable but still at risk)

Experiment	Result			
		Top layer	Middle layer	Bottom layer
Specific gravity		1.93	2.02	1.89
Liquid Limit		22.9%	16.8%	35%
Std Proctor test	OMC	20%	15%	15%
	MDD	1.47%	1.58%	1.62%
Sieve Analysis	Cu	4.79	4	3.55
	Cc	1.01	1	0.88
Direct shear test	C	30 kg/cm^2	45 kg/cm^2	60 kg/cm^2
	Φ	9 degree	6 degree	3 degree

Fig 1 tabular column of results

Conclusion :

The results of this study indicate that the landslide susceptibility of the Kethikal region is significantly high, particularly in the top soil layer, which has a Factor of Safety (FoS) of 1.12. This low value suggests that even minor triggering events, such as heavy rainfall or seismic activity, could induce slope failure. The middle and bottom layers, with FoS values of 1.2 and 1.3, respectively, exhibit slightly higher stability but still remain vulnerable under extreme conditions.

Based on these findings, it is evident that urgent mitigation measures are required to enhance slope stability and reduce landslide risk. Two primary stabilization techniques are recommended: benching and soil nailing. Benching involves modifying the slope geometry by creating horizontal steps, which helps to redistribute gravitational forces and improve surface drainage, thereby reducing erosion. Soil nailing, which consists of inserting steel bars into the slope, enhances shear strength and prevents soil displacement, further reinforcing the stability of the slope.

GIS-based hazard maps provide valuable insights for urban planners and disaster management authorities by identifying high-risk zones and assisting in the design of early warning systems. The results also emphasize the importance of continuous monitoring and assessment of slope conditions, particularly in areas with fluctuating environmental factors. Future research should focus on integrating remote sensing technologies and IoT-based geotechnical sensors to enable real-time monitoring and predictive analysis of landslide-prone areas. By implementing these strategies, it is possible to mitigate risks, protect infrastructure, and ensure the safety of local communities.

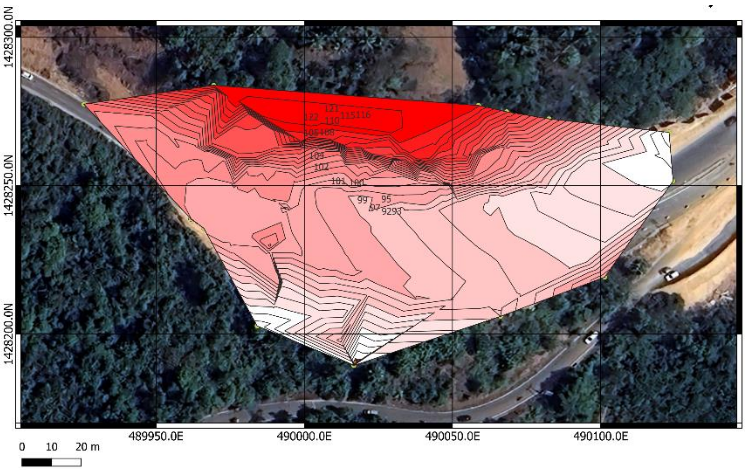

Figure 2 contour highlights of the slope

List all the material used from various sources for making this project proposal

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