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Landslide Susceptibility Mapping: A Case Study in Thenmala Sub-Watershed, Southern Western Ghats, India

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Abstract

The study intended to evaluate the landslide susceptibility in sub-watershed area with contrasting structural elements in the southern Western Ghats, Kerala India, using remote sensing and GIS techniques. In order to model landslide susceptibility, data from various sources, such as, topographical maps, geological data and satellite images were collected and processed to generate a spatial database in a GIS platform. As landslides are influenced by several environmental determinants, different factors, such as slope, distance from drainage segments, lithology, distance from lineaments, land use/land cover, and precipitation distribution, should be considered for the analysis. Further, landslide locations of the study area could be identified from satellite images and field survey. The main objective of the study was to describe the association between landslide and landslide conditioning factors for Thenmala sub-watershed regions using the weights-of-evidence method and to create landslide susceptibility map of the study area. Landslide locations were used to validate the results of the landslide susceptibility map. Hence, the study has special significance with respect to the planning and management of mountainous landscapes in the State of Kerala.

Keywords GIS, India, landslide hazard zonation, mountainous regions, slope

Introduction

A landslide describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. Landslide susceptibility and hazard zoning, and to a lesser extent, landslide risk zoning, have experienced extensive development during the last few decades [1]. The materials may move by falling, toppling, sliding, spreading, or flowing. Although landslides are primarily associated with mountainous regions, it also occurs as cut-and fills failures, river bluff failures, lateral spreading landslides, collapse of mine-waste piles, and a wide variety of slope failures associated with quarries and open-pit mines [2]. Landslide hazard and risk analysis, like many other forms of risk management of either natural or anthropogenic related hazards [3], is a relatively new discipline.

Recent studies on landslide reveal that state is multi-hazard prone and about 14.4% of the state is landslide prone. Therefore, in order to mitigate any damage arising from landslides, it is necessary to scientifically assess area susceptible to landslides. Landslide susceptibility mapping is predominantly a function of slope and combinations of slope, concavity/convexity and aspect. Next to topography factors, geology, geotechnical properties, climate, vegetation and anthropogenic factors such as development and clearing of vegetation are other important factors to be considered [1]. This study was particularly planned to analyze landslide prone area and constructing the vulnerability maps using GIS and Remote sensing tools.

Study area

Thenmala sub-watershed is a part of ecotourism destination located on the southern ends of Western Ghats in Pathanapuram Taluk of Kollam district,

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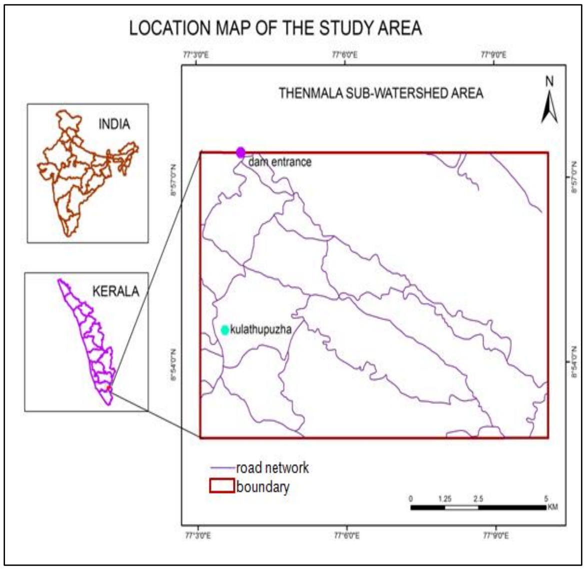

Figure 1. Location map of the study area, Thenmala sub-watershed

Kerala. The dam, which impounds the largest reservoir in the state, was built under the Kallada Irrigation and Tree Crop development project. Geologically, the study area lies between 8°52’39” to 8°57’20”North latitude and between 77°11’28” to 77°04’13” East longitude. The climate in the tract is moderately hot and humid. The average temperature varies from 17°C to 35°C. The average annual rainfall is about 2600-3000 mm. The area has closed and open forest, water body, mixed jungle and trees, different types of vegetation and agriculture, tribal catchments and other settlements. The study area mainly consists of soil types of Gravelly clay, loam, gravelly loam and clay. Figure 1 depicts the spatial representation of the study area.

Methodology

The study aimed to carry out a landslide susceptibility analysis by applying the weighted overlay approach. For the landslide-hazard analysis, the main steps were data collection and construction of a spatial database from which the relevant factors were extracted, followed by the assessment of the landslide hazard using the relationship between the landslide and landslide-related factors, and validation of the results [4]. Major data used in the study were based on Survey of India Toposheets of No. 58 H1 (map scale-1:25,000), the ArcGIS ver. 9.3, ERDAS imagine ver.8.3 and remotely sensed image dated 11-March-2015.

A Digital Elevation Model (DEM), a digital cartographic dataset of elevations in xyz coordinates, is an effective means to view the surface morphology of the area and thus, was also used in the study [5-6]. For creating a landslide inventory map slope, drainage density, geomorphology, land use, relative relief and lithology databases were constructed; and spatial analysis was done by the interpretation of aerial photographs and high resolution satellite imagery.

Using the available data and the constructed spatial database, landslide susceptibility mapping was performed by employing weighted overlay method. Weighted overlay is a simple bi-variate statistical method wherein weights are assigned based on the relationship of landslide causative factors with the landslide frequency. Numerical weightages are assigned to causative factors on the basis of their relationships to the landslide frequency. Finally, the data layers were overlaid to produce Landslide Hazard Zonation map. The processes involved in the methodology are depicted in Figure 2 [7]. A land slide susceptibility map is presented which can serve as the first generation map on which subsequent detailed information can be incorporated [8].

Results and Discussion

Landslides are natural phenomena that are often difficult to predict because they are uncertain with potentially detrimental consequences. Phenomena,

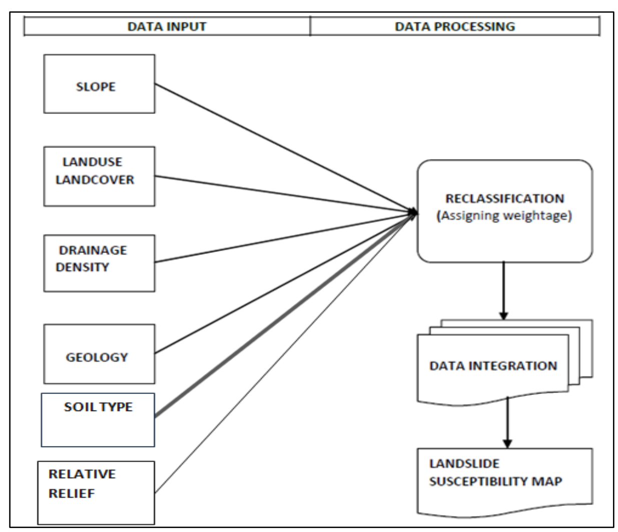

Figure 2. Flow chart representing the processes in the methodology

Table 1 Adapted criteria and weightages for different thematic layers

S. NO.	Parameter	Class	Rank	Weightage
1	Slope	0-10	1	30
		10-15	2	
		15-20	3	
		20-25	4	
		25-51	4	
2	Drainage density	0-2	4	20
		2-4	3	
		4-6	2	
		6-8	1	
		8-11	1	
3	Geomorphology	Denudational structural hill	2	15
		Lower plateau	4	
		Piedmont zone	3	
		Valley	3	
		Water body	1	
4	Soil type	Clay	4	5
		Gravelly clay	2	
		Gravelly loam	1	
		Loam	3	
6	Land use	Water body	1	10
		Open scrub	3	
		Forest plantation	2	
		Mixed jungle	2	
		Vegetation	2	
		Built up	4	
		Mixed trees	3	
		Agriculture	2	
7	Relative relief	0-3	1	20
		3-7	1	
		7-11	2	
		11-14	3	
		14-18	4	

uncertainty and potential consequences need to be captured by mapping and other systematic description procedures. In the study, all the generated thematic layers were reclassified in Arc GIS software by assigning the weightages to each class of the thematic layer from 0 to 5 on the scale in which 5 and 0 denotes the highest and least contributor towards the landslide, respectively. Reclassified layers were overlaid in Arc GIS spatial analyst tool and final map was prepared. The study area was classified into five landslide susceptible zones from very low, low, moderate, high and very high [9]. Adapted criteria and weightage for different thematic layers are shown in Table 1 and final landslide susceptibility map is shown in Figure 3.

Conclusion

The present study shows that remote sensing techniques aided by GIS can provide a useful tool for studying potential landslide areas. The accuracy of the final result depends on the parameters that

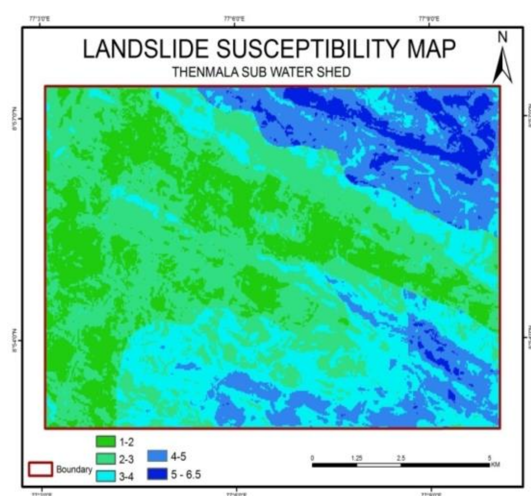

Figure 3. Landslide susceptibility map of the study area for 2015

are included in the dataset; the parameters accounted here showed better outputs. The results indicated a higher landslide risk in denudational structural hill in Thenmala sub-watershed region.

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