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GIS Based Landslide Hazard Potential Analysis

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***Abstract*—This paper presents a GIS based framework for systematic landslide hazard analysis by using various causative factors such as slope, soil, land use and land cover, elevation, geology and geomorphology. Landslide hazard zonation helps in identifying strategic points and geographically critical areas prone to landslides. Landslide hazard maps are useful for town planners to plan civil constructions in relatively safe zones. In addition, environmentally unstable slopes can be given adequate attention by planning suitable control measures**

***Keywords*—landslide; hazard map; geology; LHZ mapping**

I. INTRODUCTION

A. General

Landslides are one of the severest forms of "land degradation" often seen in hills and are very often associated with biotic interference. A study by WHO reveals that not only in India but world over degradation of environment in combination with overcrowding take people to high risk areas making the problem more complex and difficult to manage.

B. Lanslide Hazard Zonation And Zonation Mapping

Losses resulting from landslides can only be reduced either by modifying the hazard event itself or by reducing human vulnerability to it. Both philosophies require the natural hazard to be zoned. Zonation is defined as the division of the land into homogeneous areas or domains and their ranking according to the degrees of actual or potential hazard.

Landslide hazard zonation denotes the division of the state into different zones of different degrees of actual or potential hazard from landslides. Landslide hazard zonation map of an area attempts to quantify and forecast the degree of slope forming material and is considered very important for zoning purposes. Its main purpose is to guide residential, commercial and industrial development away from identified hazard zones.

C. Objective

To prepare a Landslide hazard zonation map of Karimkunnam panchayat in Thodupuzha block in Idukki district and to identify geographically critical areas prone to landslides.

II. STUDY AREA

The area selected for the purpose of study was Karimkunnam panchayat in Thodupuzha block of Idukki district. It lies between latitude 90 49' and 90 53' North and longitude 760 40' and 760 44' East. The total area of extension is about 22 km^2. In recent years, Thodupuzha region has witnessed many numbers of landslides that caused tremendous damage to lives and property. The map showing the location of Karimkunnam panchayat is shown in fig 1.

III. METHODOLOGY

Landslide Hazard Zonation mapping demarcates hill slopes into zones of varying degree of stability on the basis of their relative hazards. This technique accounts for inherent causative factors responsible for slope instability and accordingly rates them depending on their influence in inducing instability. These include: a) slope b) soil type c) land use and land cover d) elevation e) geology and f) geomorphology. Hazard probability of a place usually depends on combined effect of all inherent parameters, which can vary from place to place.

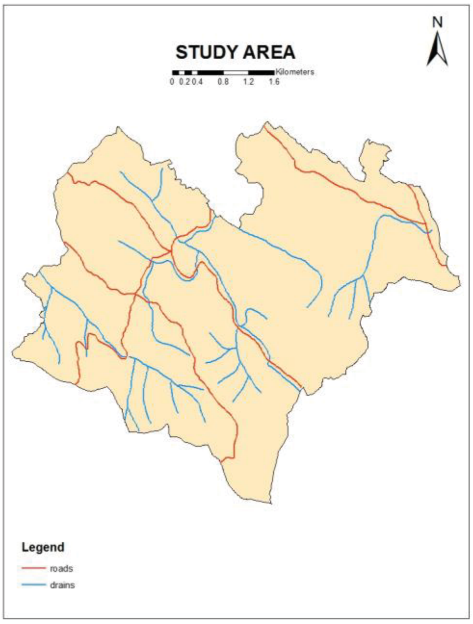

Figure1: Study Area - Karimkunnam panchayat

A. Landslide Hazard Evaluation Factor (LHEF)Rating Scheme

LHEF rating scheme takes into consideration individual and net effect of all causative factors responsible for Slope Instability. Inherent factors are used for preparation of Landslide Hazard Zonation mapping. Maximum value of ratings for individual parameter is awarded keeping in mind its estimated significance in causing slope instability and also to represent overall field conditions. Various causative factors and their corresponding LHEF rating values are shown in Table 1.

1) Slope

Slope is a very important parameter in any landslide hazard zonation mapping. If the slope is higher, then there is a higherchance of occurrence of landslide. The slope map of the study area is prepared from the Digital Elevation Model (DEM) and for the preparation of the DEM the SRTM (Shuttle Radar Topographic Mission) data was used. The SRTM data was used to make the Triangulated Irregular Network (TIN). Then this TIN is converted to DEM using ArcGIS software. From DEM, slope map in degrees can be prepared. Suitable LHEF ratings were given according to the steepness of slope (Table 2). The slope map thus prepared is shown in fig. 2

2) Soil

Soil type is one of the important parameters governing slope stability. Presence of huge thickness of loose soils when mixed with rainwater, triggers the landslide. The soil map and soil data was obtained from Kerala State Land Use Board. The soil map of the study area mainly comprised of four soil series K11, K36, K35 and K33. The soil map was scanned, georeferenced and then digitised using the editor tool in ArcGIS. Then the LHEF rating was given to each soil series according to their ability to cause slope instability. The digitised map was then converted into Raster and then reclassified with respect to LHEF rating given. The description of soil series are as follows:

K11 - Very deep, well drained, gravelly clay soils on gently sloping mid-land laterites with valleys of central Kerala, with moderate erosion; associated with deep, well drained clayey soils with coherent material at 100 to 150 cm on gentle slopes.

K36 - Very deep, well drained, clayey soils on moderately steeply sloping high hills with thick vegetation, with moderate erosion; associated with deep, well drained gravelly loam soils on gentle slopes.

TABLE 1: MAXIMUM LHEF RATING FOR DIFFERENT CAUSATIVE FACTORS (ANBALAGAN ET AL., 2008)

Causative Factor	Maximum LHEF rating
Slope	2.0
Soil type	2.0
Land use and land cover	2.0
Elevation	1.0
Geology	2.0
Geomorphology	2.0

K35 - Deep, well drained, gravelly clay soils with coherent material at 100 to 150 cm on moderately sloping isolated hillocks, with severe erosion; associated with moderately shallow well drained, gravelly loam soils with coherent material at 50 to 75 cm on very gentle slopes, moderately eroded.

K33 - Deep, well drained, gravelly clay soils on moderately sloping medium hills with thin vegetation, with severe erosion; associated with rock outcrops.

The LHEF ratings for different soil types are given in table 3 and the soil map prepared is shown in fig. 3

3) Land Use and Land Cover

Vegetation has major role to resist slope movements. A well spread network of root system increases shearing resistance of slope material due to natural anchoring of slope materials. Moreover, thick vegetation reduces action of weathering and erosion and hence adds to stability of the slopes. On the other hand, barren or sparsely vegetated slopes are usually exposed to weathering and erosion, thus rendering it vulnerable to failure. With increasing urbanization, water due to domestic usage may be released on the slope surface wherever the drainage measure is inadequate. This water may get added up to the subsurface water and may develop pore water pressure, leading to slope instability. It not only removes vegetation cover but also adds to the natural weight of the slope as surcharge due to weight of civil structures. The Land use and Land cover map was obtained from Kerala State Land Use Board. The map was then georeferenced and digitised in ArcGIS. About seven land use types were identified from the study area and suitable LHEF ratings were given as shown in Table 4. The land use and land cover map of the study area is shown in fig. 4

4) Elevation

Elevation also plays a major role in combination with other factors for causing landslides. Landslides are common in areas of high elevation with steep slopes. Elevation map for the study area is prepared from the DEM. It gives the elevation of all points in the study area with respect to a reference datum. Appropriate LHEF ratings given for different elevation range is shown in table 5. The elevation map of the study area is shown in fig. 5

5) Geology

Geology is an important factor controlling slope stability. The geology map was obtained from Centre for Environment and Development. In the study area, three types of rocks were identified, namely charnockite group of rocks, Khondalite group of rocks and migmatite complex. Appropriate LHEF ratings for various classes is given in table 6.The geology map of study area is shown in fig. 6

6) Geomorphology

Geomorphology is the out shaping of the landmass as an expression of the dynamic evolutionary processes. The geomorphology map for the study area was obtained from Centre for Environment and Development. In the study area, six prominent landforms were identified, namely denudational structural hills, denudational hills, residual hills, piedmont zone, plateau and pediplain. The appropriate ratings for various classes is shown in Table 7 and the geomorphology map is shown in fig. 7.

TABLE 2: RATINGS FOR SLOPE (ANBALAGAN ET AL., 2008)

Slope angle	Rating
> 60°	2.0
40 - 60°	1.8
30 - 40°	1.6
20 - 30°	1.4
10 - 20°	1.2
< 10°	1.0

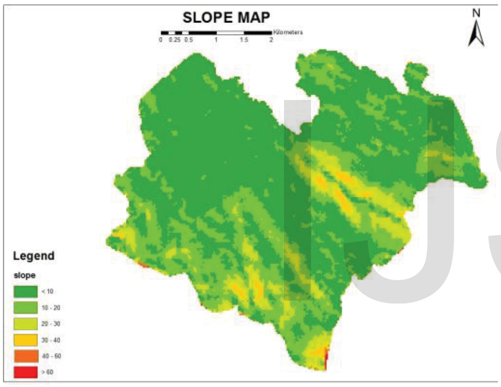

Figure 2: Slope map

TABLE 3: RATING FOR SOIL TYPE (ANBALAGAN ET AL., 2008)

Soil series	LHEF rating
K11	2.0
K36	1.8
K35	1.6
K33	1.4

TABLE 4: RATINGS FOR LAND USE AND LAND COVER TYPES (ANBALAGAN ET AL., 1992)

Land Use type	LHEF rating
Waste land	2.0
Built up	1.8
Crop land	1.6
Plantation-Coconut	1.4
Mixed trees	1.3
Plantation-Rubber	1.0
Rocky area	0.8

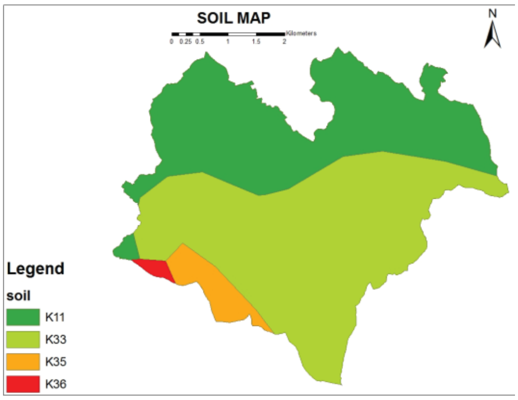

Fig 3: Soil map

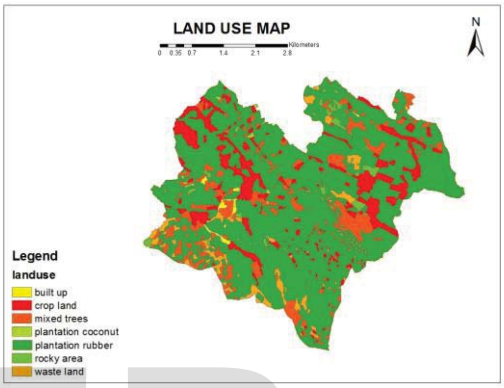

Fig 4: Land use and land cover map

TABLE 5: RATINGS FOR ELEVATION (ANBALAGAN ET AL., 1992)

Elevation (m)	LHEF rating
> 300	1.0
200 - 300	0.8
100 - 200	0.6
< 100	0.4

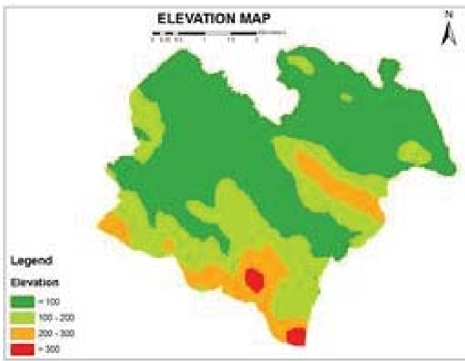

Fig 5: Elevation map

TABLE 6: RATINGS FOR GEOLOGY (ANBALAGAN ET AL., 2008)

Geology	LHEF rating
Khondalite group of rocks	2.0
Migmatite complex	1.8
Charnockite group of rocks	1.5

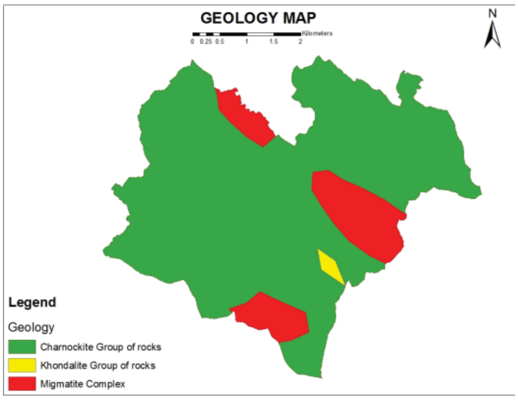

Fig 6: Geology map

TABLE 7: RATINGS FOR GEOMORPHOLOGY (ANBALAGAN ET AL., 2008)

Geomorphology	LHEF rating
Denudational structural hills	2.0
Denudational hills	1.8
Residual hills	1.6
Piedmont zone	1.4
Plateau	1.0
Pediplain	0.6

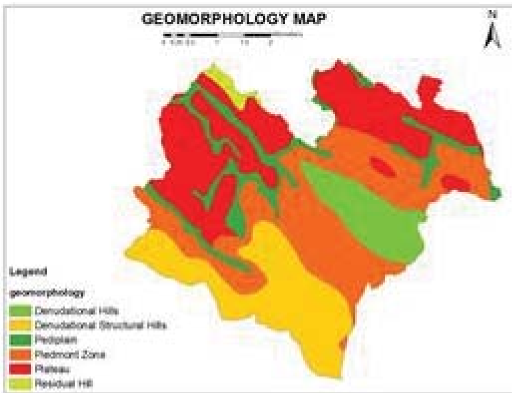

Fig 7: Geomorphology map

B. Calculation Of Total Estimated Hazard (Tehd) From Lhef Ratings

TEHD is calculated by adding LHEF ratings obtained for individual parameters. The final TEHD value indicates overall condition of instability. Landslide hazard zonation map on of an area is prepared from TEHD values. The TEHD can be calculated using the overlay analysis in ArcGIS. On the basis of range of TEHD values, an area can be categorized into four classes of relative hazard zones; Low hazard (LH) zone, Moderate hazard (MH) zone, High hazard (HH) zone and Very high hazard (VHH) zone. A LHZ map will show spatial distribution of these hazard zones and accordingly help town planners to select relatively safe areas for future development.

C. Overlay Analysis

Overlay analysis is done to obtain the Landslide Hazard Zonation map. Maps for each causative factor are prepared with the help of ArcGIS and suitable LHEF ratings were given. Then these were overlaid using ArcGIS to obtain the final LHZ map. Several overlay techniques are available in ArcGIS of which the Raster calculator was used in the current study. It calculates the TEHD value for each pixel and gives the final landslide hazard zonation map.

IV. RESULTS AND DISCUSSIONS

The final Landslide Hazard Zonation map is prepared by overlaying the causative factor maps in ArcGIS. Here Raster Calculator is used for overlay analysis. The resulting map is based on Total Estimated Hazard (THED) value which is the sum of the Landslide Hazard Evaluation Factor (LHEF) rating for each causative factor. Based on the THED value obtained, the final map can be categorized into four classes of relative hazard zones (Table 8); Low hazard (LH) zone, Moderate hazard (MH) zone, High hazard (HH) zone and Very high hazard (VHH) zone.

The maps overlaid for the preparation of Landslide hazard zonation map are Slope map, Soil map, Elevation map, Land use and Land cover map, Geology map and Geomorphology map. From the final hazard map (Fig. 8), area for each hazard zone was calculated and the areas of very high hazard zone were identified to be near Nellapara and Illiari. The area statistics of landslide hazard zones are shown in Table 9.

TABLE 8: LANDSLIDE HAZARD ZONES BASED ON TOTAL ESTIMATED HAZARD (ANBALAGAN ET AL., 2008)

Hazard zone	Range of TEHD value	Description of zone
I	< 7.0	Low hazard (LH) zone
II	7.0 – 7.5	Moderate hazard (MH) zone
III	7.5 - 8.5	High hazard (HH) zone
IV	> 8.5	Very high hazard (VHH) zone

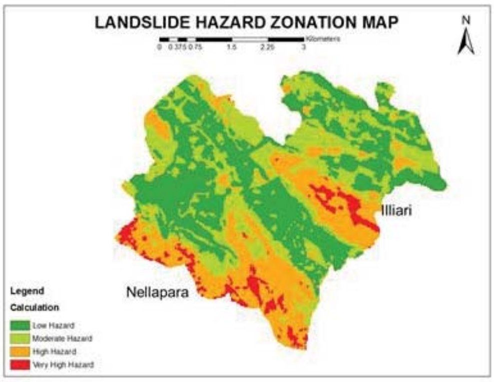

Fig 8: Landslide Hazard Zonation map

TABLE 9 AREA STATISTICS OF LANDSLIDE HAZARD ZONES

Landslide hazard zone	**Area (km^2)**	**Area (%)**
Low hazard	8.433	39.14
Moderate hazard	6.561	30.45
High hazard	5.601	26
Very high hazard	0.95	4.41

V. CONCLUSIONS

This study shows a simple and cost effective way of using geographical information system for creating Landslide hazard zonation map from the available data base. In this study, an attempt has been made to prepare landslide hazard zonation map for the Karimkunnam panchayat. From the landslide hazard zonation map, the area of low hazard is found to be 8.433 Km^2, area of moderate hazard is found to be 6.561 Km^2, area of high hazard is found to be 5.601 Km^2, area of very high hazard is found to be 0.95 Km^2.

Low Hazard zones are considered safe for civil constructions. Hill slopes falling in Moderate Hazard zones are also safe for construction practice, but may contain local pockets of instability, which should be suitably accounted during constructions. For areas falling in High Hazard and Very High Hazard zones, it is always advisable to avoid constructions.

Constructions are steadily growing without taking into consideration existing instabilities. Availability of Landslide Hazard Maps would pave way for effective landslide disaster mitigation and Management, through effective land use planning.

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