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# An approach for remote sensing and GIS based landslide hazard zonation mapping in Sirumalai Hill, Tamil Nadu

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**ABSTRACT**

Landslide is among the major hydro-geological hazards that affect large part of India, especially Western Ghats and Eastern Ghats. The paper presents an integrated GIS and Remote sensing approach for Landslide Hazard Zonation in part of Sirumalai hill, Tamil Nadu. Satellite data, topographic maps, field data and other information maps are used to the study were prepared in GIS environment. Numerical rating scheme for the factors was developed for the spatial analysis in GIS environment to arrive at landslide Hazard Zonation map of the area. Landslide Hazard Index (LHI) value is calculated and landslide hazard zonation is decide by the LHI histogram. The resulting of the landslide Hazard Index Frequency Mapping is classified in five classes: very high, high, moderate, low, very low. Field data on landslide bodies are used to evaluate and validate the LHZ Map.



## Introduction

Landslides constitute one of the major natural catastrophes, which account for considerable loss of life and damage to communication routes, human settlements, agricultural field and forestland. Most of the terrains in mountainous areas have been subjected to slope failure under the influence of variety of terrain factors and figured by events such as extreme rainfall or earthquake. Hence there is a need for landslide Hazard Zonation (LHZ) map for identification of potential landslide areas. In recent years several works have been carried out all over the world for LHZ mapping.

Therefore different approaches adopted by different workers ([1]Anbalagan 1992, [2]Jade and Sarkar 1993, [3]Gupta and Joshi 1990). The basic difference among these approaches lies in the assignment of numerical weights to the landslide causative factors [4] Wang Jain and Peng Xiang-guo(2009). Over the past few years, Geographic Information System (GIS) has gained significant importance for spatial data analysis. It has been proved to be a very powerful tool for landside study [5] Bonham-carter (1995).

The present study is an attempt towards development of a methodology for landslide Hazard Zonation mapping. This involves with generation of thematic data layer and their spatial analysis within the part of Sirumalai hill Dindigul district.

## Study Area

Sirumalai is the eastern –most outcrop or spur of the Western Ghats and an independent range, and the Sirumalai range stretches about 45 km on the Dindigul- Madurai road with its width being about 15 – 25 km. There is no independent range in Tamil Nadu which is as big as with many comparable ranges in Tamil Nadu. The hill has a cool climate it is 12, 00MSL meters high and spreads over 60,000 acres. One third of the area belongs private revenue land on which grows coffee, cardamom, black pepper, banana and lemon.

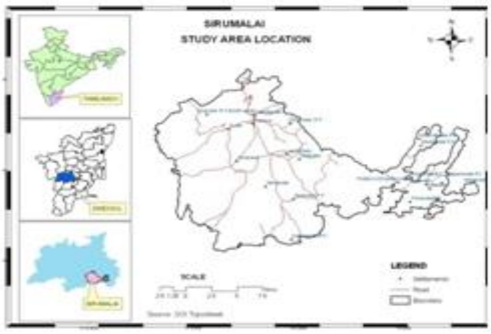


**Figure1. Study area**

Sirumalai is a small hill and is located in Dindigul district, Tamil Nadu, India his between 10° 07' N longitude and 77° 55' E longitude. They are an isolated, compact group of hills stretching about 6.5 km south of Madurai city. The hills are rectangular in outline, having 19.3 km length towards north south and 12.8 km width east-west, covering an area of 288.3sqkm. The maximum rainfall occurs during the North eastern monsoon months from October to December.

## Data source

The different types of datasets used were as follows:

1. Topographic maps of survey of India at 1:50,000 scale to from the base map.
2. Geology and Geomorphology maps driven from Geological survey of India.
3. Satellite Sensor data IRS LIIS IV with 5.8mtr resolution.
4. Field data involving observations on landslide and land use/land cover.

All the topographic maps registered from an input into the GIS database.

## Methodology

The landslide Hazard Zonation analysis is very difficult task, because the result of layer interaction is complex for the factor. In this paper, we analyzed the landslide susceptibility in two ways. One is the qualitative map combination where, the relative weighting values are assigned to the factors and their

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classes on the basis of field knowledge and experience. The other approach is to compute the weighting values based on the relationship of the factors with existing landslides by the use of statistics. In present attempt we have adopted a technique of qualitative map combination by developing a rating system, which is based on the relative importance of factors influencing slope instability in the study area.

The Methodology involved selection of factors, data layer generation in GIS, assignment the numerical rating value to factor, data integration in GIS, computation of the landslide potential index, landslide susceptibility and validation of the resulting map. An attempt was also made to validate the map with existing landslide distribution and statistic significance test. This methodology is shown in (figure2).

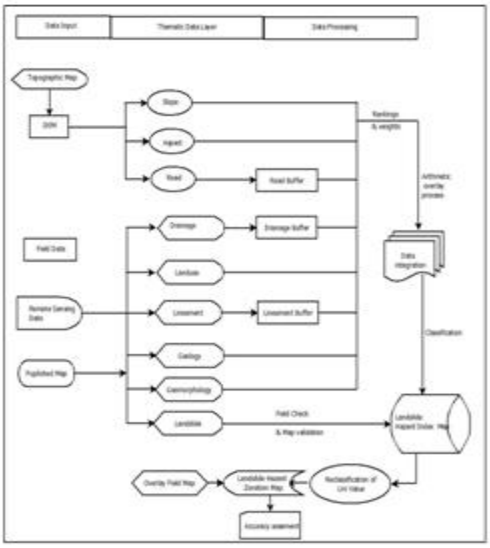

**Figure2. Flow diagram showing the methodology**

**Data Layer Preparation**

For the landslide susceptibility mapping following data layers was prepared:

- Digital elevation model
- Slope Map
- Aspect Map
- Drainage Buffer Map
- Lithology Map
- Structure Buffer Map
- Road Buffer Map
- Land use / land cover Map

The details of these layers are described in the following paragraphs.

5.1, DEM- based derivatives, A Digital Elevation Model (DEM) represent the spatial variance in elevation. The DEM (prepared from survey of India Toposheets 1: 50,000 scale and contour interval is 20 mtr) was used to generate Slope map and Aspect map.

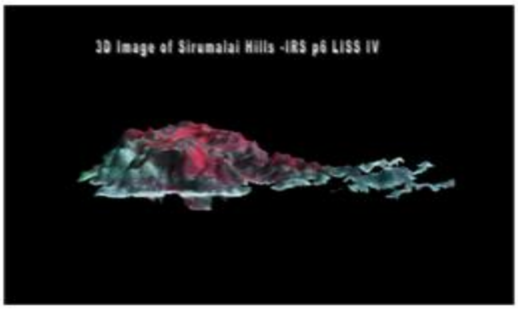


**Figure3. Digital Elevation Model**

Slope is an important parameter for stability consideration. A slope map was generated with 30 meter grid cell size from DEM. The slope angle is calculated from DEM had range of $0^o$ - $83^o$. A slope aspect map with 30-m gird cell size was also generated from DEM.

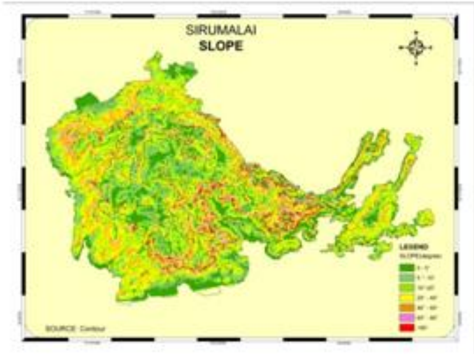


**Figure4. Slope map**

5.2, Structural and Lithological Features, Structure and lithology are among most important parameters for landslide susceptibility mapping. The lithology map derived from geological map (1:50,000 scale) of the Sirumalai Hill- Dindigul area and field verification. After field verification to prepare the lithological map (Figure5). There are two rock types namely charnockite and quartzite in this area.

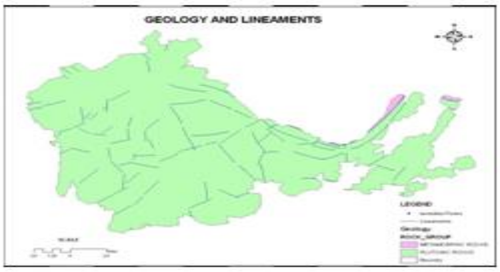


**Figure5. Geology and Lineamnets map**

The lineaments showing fractures, discontinuities, and shear zones were interpreted from the LISS IV image. Distance function was applied to create buffer zones around the lineament. The distance from structural features as likelihood of occurrence of landslides may increase with the proximity to these features. These were verified at a few locations in the field.

5.3 Landuse/Landcover is an important parameter for landslide susceptibility mapping. The Landuse/Landcover classes are identified which are as follows: forest cover, plantation, built-up area and water bodies. The IRS 1D LISS IV image data were classified using the unsupervised classification. The topographic maps, field data were used as a reference data. Finally unsupervised classification technique was used to prepare the land use / Landcover map. After preparing the map, it was again checked in field, we observe some errors. Finally the land use transferred to GIS.

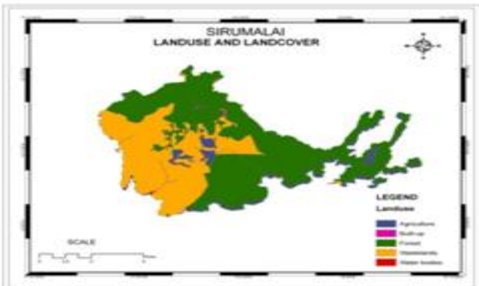


**Figure6. Landuse / Landscover**

5.4. Drainage, The drainage map was prepared from the topographic maps with additional inputs from satellite images. The under cutting action of the channels may induce instability of slopes. Hence some of the major drainage segments were digitized to convert the raster format and buffered.

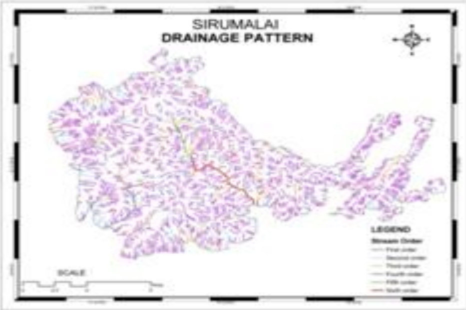


**Figure7. Drainage**

5.5. Road. One of the controlling factors for the stability of slopes is road construction activity. For this factor road map was generated in order to identify the landslide frequently along the roads, due to inappropriate cut slopes and drainage from the road.

5.6. Landslide. A systematic field study of the landslide was carried out along the road section running parallel to the Sirumalai Hill. They are different types of landslide occurring in this area, namely rock slide, mud slide, totally occurred in 73 times. The field data on distribution of landslide was used as a ground check in the analysis of landslid e susceptibility mapping


**Figure8. Landslide Map**

5.7. Ranks and weights. The weighting – rating system based on the relative importance on various causative factor derived from field knowledge. In this scheme the factors were assigned numerical ranking on 1-9 scale in order to importance. Weights were also assigned to the classes of the factors on 0-9 ordinal scale where higher weights indicate to more influence for landslide occurrence .In the scheme was suitably modified by undertaking several iterations using different combination of weights. The different class in each theme are assigned knowledge based ranking Hence each thematic layer is assigned a weight based on their influence on the landslide occurrence [6]. The rating scheme given in table described below.

In the present study most of the landslide observed from road cutting slopes and drainage hence the maximum weight was assigned to road 100m buffers. The next important factor was considered on drainage; here the maximum weight was given to 200m. The Convex slopes are more prone to landslide, the slope classes weights are assign descending order. Occurrence of landslide is depends on the landuse type, hence a maximum weight assign to barren land and minimum weight is assign to water bodies, based on the field observation. Lineaments are the important factor because the highly fractured and joined formation showed more potential to landslide. Here the maximum weight is assign to 100m buffer. Slope and aspect has an indirect influence on slope instability. In general south facing slope have a lesser vegetation, compared to north facing slope; hence, erosion activity is relatively greater in the former case [7]. Based upon the landslide distribution, south – and east-facing slopes were considered to have more potential for landslides [8]. Considering these facts and field observation, slope and aspect class were given weights accordingly.

**Data integration and Landslide susceptibility mapping**

The numerical data layers representing weight values of the factor classes as attribute information were generated from the thematic data layers for data integration and spatial analysis in the GIS. The input data layers were multiplied by their corresponding ranks and were added up to obtain landslide potential Index (LPI) for each 30 – by 30-m cell; i.e.

$$LPI = \sum_{i=1}^{9}(R_i \times w_{ij})$$

Where $\mathbf{R_i}$ denotes the rank for factor i and $\mathbf{w_{ij}}$ denotes the weight of class j of factor i.

The arithmetic overlay approach built into ArcGIS 9.3 model builder was adopted for this, such an arithmetic overlay process accepts both continuous and discrete grid layers, and the derived data are continuous gird data layers [9,10].The landslide susceptibility map was classified in Very high, High, Moderate, Low, Very low for the relative potential zones are shown in Figure 9.

**Landslide Hazard Zonation**

The LHI frequency Quintiles value was studied and used the landslide hazard zonation. The frequency Of LHI value is Classified in five Quintiles. They are shown in 26,30,33,38 and 58. Using the LHI values is classified the study are into five Zone very low, low, moderate, high and very high landslide occurrences.

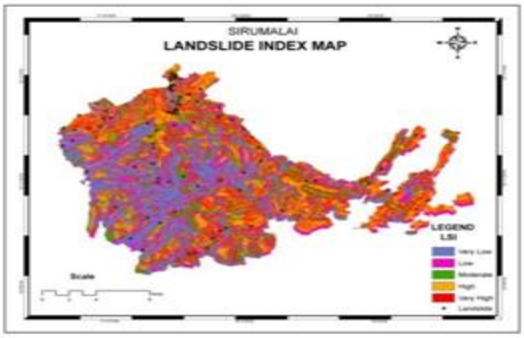


**Figure 9. Landslide Index Map**

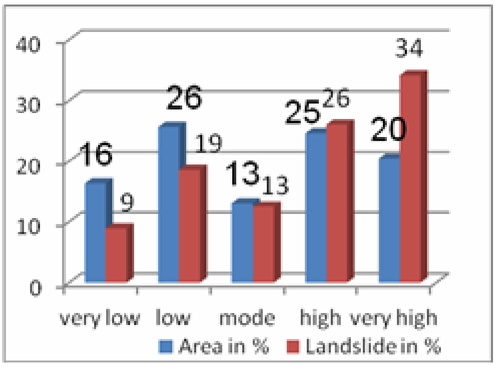


**Figure.10.Landslide Hazard Zones**

**Comparison of LHZ map with field data**

The distribution of existing landslide (field data) was used to evaluate the landslide hazard zonation map. The landslide location were digitized and overlaid from LHZ map. These maps are prepared in GIS-based study, Comparison of present area and active landslide incidence for each LHZ class, shown in Figure 10. The 'very high hazard zone' covers only about 20% of the total area but has very high (34 %) frequency of landslide occurrences. Furthermore the landslide frequency in the high hazard zone is also high (26 %) in comparison to the area (25%). The moderate zone covers 13% of the area and has 13% of the landslide occurrence. Low and very low zone areas covered 42% of the study area and contains only 24 landslides, which constitute 25% of the landslide studied. It is consider that the landslides in Very high, high and moderate hazard zones may be more governed by local effect.

**Conclusion**

The numerical rating scheme is very suitable methodology for landslide Hazard index mapping. In the present study Remote sensing and GIS tools were used to generate thematic layers and developing a Landslide hazard zonation map. The methodology of rating scheme was improved iteratively by evaluating the results. However the rating scheme not suitable for other place because the landslide involving factor was varies from region to region. Finally landslide susceptibility mapping classified in five different zones. The result was validated on the basis of landslide distribution. However improve the map quality to incorporating more factors and maps correlate the field. Further any change in the natural environment and human interference in the landslide Hazard Zone area the map should be updated periodically. The landslide Hazard Zonation maps helps in decision making, hence implementing a hilly area development.

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| Data layers | | Classes | Weighting | Rating |
|---|---|---|---|---|
| Slope | 1. | 0-10 | 9 | 0 |
| | 2. | 10-20 | | 2 |
| | 3. | 20-30 | | 6 |
| | 4. | 30-40 | | 8 |
| | 5. | 40-50 | | 9 |
| | 6. | 50-60 | | 7 |
| | 7. | 60-70 | | 5 |
| | 8. | 70-80 | | 4 |
| | | | | |
| Drainage Buffer | 1. | 100m | 8 | 9 |
| | 2. | 200 m | | 7 |
| | 3. | 300 m | | 5 |
| | 4. | 400 m | | 2 |
| | 5. | 500 m | | 0 |
| | | | | |
| Road Buffer | 1. | 50 m | 7 | 9 |
| | 2. | 100 m | | 8 |
| | 3. | 150 m | | 5 |
| | 4. | 200 m | | 3 |
| | 5. | 250 m | | 2 |
| | | | | |
| Landuse | 1. | Deciduous | 6 | 2 |
| | 2. | Mixed forest | | 4 |
| | 3. | Water body | | 0 |
| | 4. | Plantation | | 6 |
| | 5. | Builtup | | 5 |
| | | | | |
| Lineament Buffer | 1. | 100 m | 5 | 9 |
| | 2. | 200 m | | 8 |
| | 3. | 300 m | | 4 |
| | 4. | 400 m | | 2 |
| | 5. | 500 m | | 0 |
| | | | | |
| Aspect | 1. | Flat | 2 | 0 |
| | 2. | North | | 1 |
| | 3. | North East | | 4 |
| | 4. | East | | 7 |
| | 5. | South East | | 8 |
| | 6. | South | | 9 |
| | 7. | South West | | 6 |
| | 8. | West | | 3 |
| | 9. | North West | | 2 |

**Table 1. Ranks and weights**