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# An Integrated Approach with GIS and Remote Sensing Technique for Landslide Hazard Zonation

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## ABSTRACT

Landslide is among the major hydro-geological hazards that affect large parts of India, especially Himalayas, North- Eastern hill ranges, Western Ghats, Nilgiris and Eastern Ghats. Landslide hazard zonation helps in identifying strategic points and geographically critical areas prone to landslides. This paper deals with an integrated approach of remote sensing and geographical information systems for landslide hazard zonation. Landslide hazard zonation simply means the division and preferably subdivision of land surface in to various zones according to the degrees of actual potential hazard caused by landslides and related phenomena. The key factor in landslide hazard mapping is the assessment and grading of risk associated with the failures. The landslide distributions are mapped by extraction of features from the satellite images. In order to analyze landslide susceptibility efficiently, the existing maps are digitized and processed with the help of integration of terrain information by GIS. Six categories of controlling factors for landslides i.e. aspect of slope, geology, land use, drainage, lineament and runoff are defined. The data obtained is integrated to form landslide hazard zonation map. An effort is made to generate a landslide susceptible map from satellite imagery, DEM (Digital Elevation Model) and maps. Finally, a map divided into four susceptibility zones is produced using the weight value of all controlling factors using the method of multi objective decision making process and then each susceptibility zone is evaluated by comparing with the distribution of each controlling factor class. Landslide susceptible map can be used to predict the occurrence of the landslide and also used for planning developmental activities in this geomorphologically fragile Nilgiris plateau.

Key words: Landslide Hazard Zonation, Landslide Analysis, Landslide Susceptibility.

## 1. Introduction

Landslide is the most costly and damaging natural hazards in the mountainous region. These landslides are triggered mainly by rainfall or earthquakes. The growing population and expansion of settlements over these hazardous areas increased the impact of natural disasters in most of these areas. The landslide hazards, in general cannot be completely prevented. However, the intensity and severity of impacts of the hazards can be minimized if the problem is recognized before the development activity. Hence, there arises a need to identify the unstable slopes, which are done by the landslide hazard zonation. The landslide hazard zonation (LHZ) of an area aims at identifying the landslide potential zones and ranking them in order of the degree of hazard from landslides.

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The Nilgiris, because of its natural charm and pleasant climate, was a place of special attraction for the Europeans but now it has entered in to an anxious era of landslides since the calamitous landslides of 1978. The frequency of landslides has increased in recent years. The worst landslide occurred in 1993 (on an average 1,000 metres in length and 150 metres in width and displacing three million tonnes of earth and rock debris). Geologists have recommended that extreme caution should be exercised in planning developmental activities in this geomorphologically fragile Nilgiri plateau. Landslide occurs without any prior indication, such unpredictability demands development of tools and techniques to study the landslide.

## 2. Study area :

Kundapallam watershed lies in the Nilgiris district of TamilNadu which is a hilly district located on the fragile environment of Western Ghats with an elevation ranging from 300 m in the Mayor Gorge to 2634 m above MSL at Doddabetta peak. Kundapallam watershed has a geographical area of 12 sq.km and is bounded by 76° 35’ 30” and 76° 37’ 30” East longitude and 11°14’15”and 11°16’15”North latitude.

It is a free basin consisting of an area of about 1753 Ha. It also consists of forest plantation (4.04%), Shola lands (6.35%), Uplands i.e., Land with or without scrubs (9.38%), water bodies (3.03%), Grass land (1.59%), Mixed land cover (5.34%) and built up area (2.16%). The climatic features of the Kundapallam watershed are, wind velocity – 5.4 Km/hr, relative humidity – 77%, annual rainfall – 1300 -2000 mm, maximum temperature – 24.3° C (summer season), minimum temperature 6.0°l C ( winter season).

## 3. Methodology

Preparation of thematic maps showing slope, landuse, geological, drainage, lineament, runoff and soil components of the landslide area using remote sensing images.These are analyzed and are numerically weighted based on their relative importance. The study area has been classified into four zones of instability and landslide hazard zonation map is formed.

### 3.1 Preparation of Thematic maps

For the preparation of thematic maps the data are collected from various sources like Survey of India Toposheet (SOI) No.58A/11 of scale 1:50,000 of 1972, IRS-1C LISS III +PAN merged satellite data , field data and various other sources were used.

### 3.2 Base map

Base map was prepared from the Survey of India Toposheet. It gives the boundary of the study area. There are 12 villages and they fall on the eastern region of the watershed. The river kunda is flowing from east to west.

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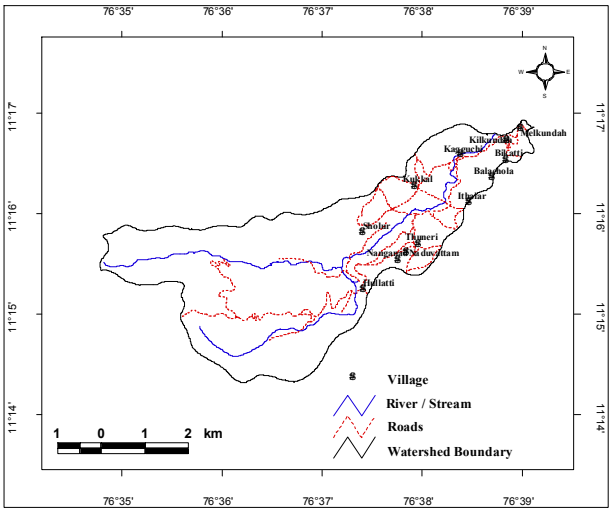


Fig : 1 Base map

### 3.3 Slope map

Slope is an important factor in the analysis of landslide. As the slope increases the probability of the occurrence of landslide increases because as the slope angle increases the shear stress of the soil increases. The slope map is derived from SOI toposheets by WENTWORTH method. The slope class was categorised as 0°-13° as moderate slope, 14°-15° as steep slope, 16°-17° as very steep slope and 18°-19° as high slope. The very steep slope is found in eastern region, steep slope is observed in the western region, villages have moderate slope and high slope occurs in agricultural and grass land

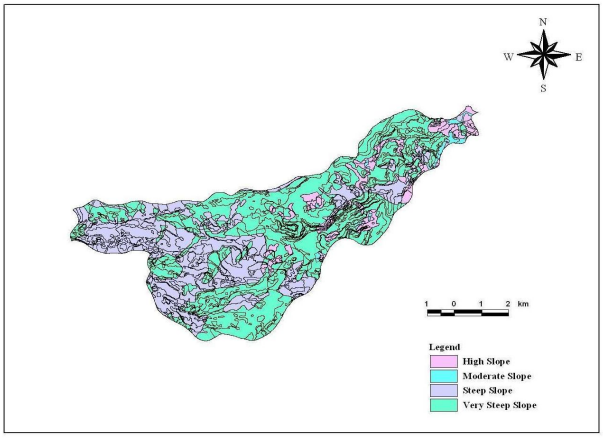


Fig : 2 Slope map

### 3.4 Landuse map

The Land use map shows the different types of land cover pattern present in the study area. Vegetation cover is an important factor which influences the occurrence and movement of the rainfall which triggers the landslide. The watershed area is characterised by the dense forest, degraded forest, agricultural land, forest plantation, grass land, horticultural plantation, land with or without scrub, open forest and villages. The horticulture plantation is found as the major landuse in the watershed.

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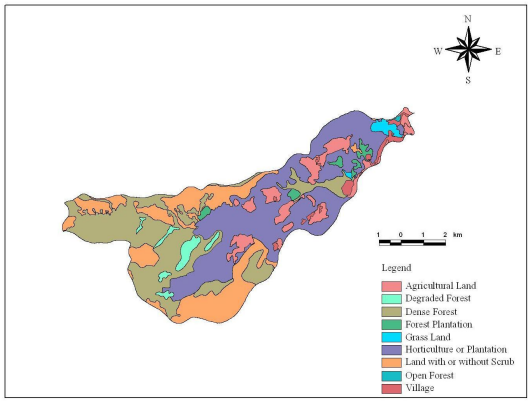


Fig: 3 Landuse Map

### 3.5 Geology map

Geology map is prepared from the geological survey of India mineral map on a scale 1:50,000. Structurally the area is highly disturbed and subjected to faulting. The watershed is entirely covered by charnockite.

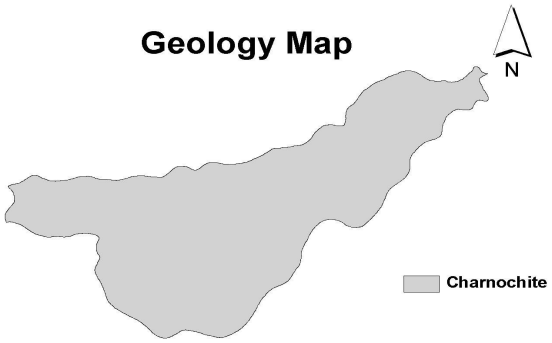


Fig :4 Geology Map

### 3.6 Drainage density map

The drainage map shows the flow of water through out the study area. As the distance from the drainage line increases the probability of occurrence of landslide also increase. The drainage density for the study area was categorized in to four zones (very high, high, medium and low). Majority of the watershed falls under high density category.

Table 1 Drainage Density Classification

| Drainage Density ($Km/Km^2$) | Classification |
|---|---|
| > 0.008 | Very High |
| 0.006 – 0.008 | High |
| 0.004 – 0.006 | Moderate |
| < 0.004 | Low |

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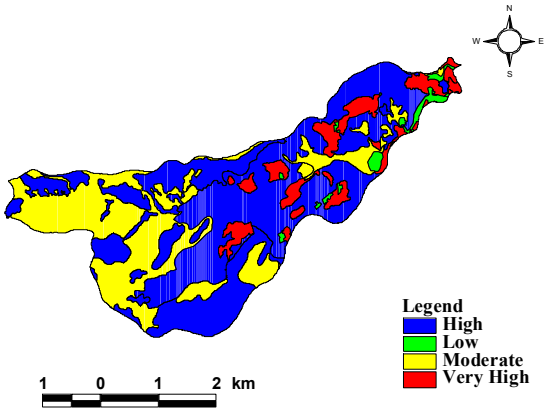


Fig: 5 Drainage Density Map

### 3.7 Lineament Density map

The lineament map shows the lineaments formed in the study area due to the geological conditions. Water flows through the cracks and the soil over this lineament would slide and hence this triggers the landslide. A lineament map was prepared by visual interpretation of the satellite data by identifying the fractures and fault lines. The lineament density is categorised in to four classes as very high, high, moderate and low as show in the table below. Majority of the watershed falls under high density category.

Table 2 Lineament Density Classification

| Lineament Density ($Km/Km^2$) | Classification |
|---|---|
| > 0.004 | Very High |
| 0.002 – 0.004 | High |
| 0.001 – 0.002 | Moderate |
| < 0.001 | Low |

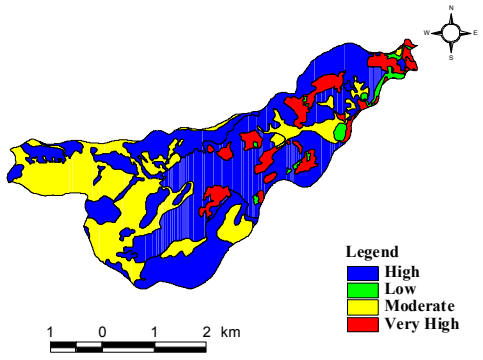


Fig: 6 Lineament Density Map

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### 3.8 Runoff map

The runoff map shows the depth of runoff which was obtained due to rainfall. The depth of runoff was calculated from the rainfall datum for the year 2004. This datum was obtained from HADP. The runoff is high for the entire watershed, with very high runoff in agricultural land which leads to severe erosion. Absence of low runoff is noted in the study area. The runoff lineament density is categorised in to four classes as very high, high, moderate and low as show in the table below.

Table 3 Runoff Classification

| Range mm | Runoff Class |
|---|---|
| 750-1600 | Very High |
| 500-750 | High |
| 250-500 | Moderate |
| 0-250 | Low |

### 3.9 Soil map:

Soil survey report of kundappallam and satellite data is used to prepare a detailed soil map and soil taxonomy. Coarse Loamy Typic Humitropepts and Coarse Loamy Typic Dystropepts were found very high in the central and eastern side of the watershed where slope was very high. The distribution of soil is shown below.

Table: 4 Distribution of soil association

| S.No | Soil Type | Soil Name | Area ($Km^2$) |
|---|---|---|---|
| 1 | KG1 | Sandy Loam | 0.21 |
| 2 | KG2 | Ultic Dystropepts | 0.26 |
| 3 | KG3 | Coarse Loamy Typic Dystropepts | 3.41 |
| 4 | KG4 | Fine Loamy Lithic Dystropepts | 0.97 |
| 5 | KG5 | Fine Loamy Typic Dystropepts | 0.17 |
| 6 | KG6 | Coarse Loamy Typic Humitropepts | 4.87 |
| 7 | KG7 | Ultic Tropudalfs | 0.02 |
| 8 | KG8 | Typic Tropudalfs | 4.83 |

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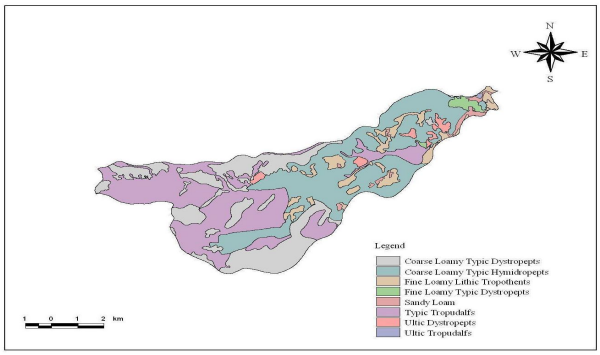


Fig: 7 Soil Map

### 3. 10 Landslide Hazard Zonation map

Landslide hazard zonation map is prepared by integrating the effect of various triggering factors. Weightage is assigned to the factors considered. The weights are assigned as show in the table below.

**Table 5 Weightage for thematic maps**

| S.NO | Theme map | Measure | Maximum Weightage |
|---|---|---|---|
| 1 | Land Use | Type of land cover | 20 |
| 2 | Slope | Degree of slope | 20 |
| 3 | Soil | Thickness of soil | 15 |
| 4 | Runoff | Depth of runoff | 15 |
| 5 | Geology | Type of rock | 10 |
| 6 | Lineament | Lineament density | 10 |
| 7 | Drainage | Drainage density | 10 |

Then criterion table is formed for landslide hazard zonation area with the help of the Soil conservation department. Suitability index of the susceptible zonation is calculated by multiplying the multiplication factor of rank with the weightage assigned for each theme.

**Suitability Index = Multiplication Factor of Rank x Weightage**

Then the summation of suitability index of each theme could give the susceptible value for individual polygons.Based on the suitability index the susceptible zonation was classified into four groups (very high, high, moderate and poor) and was ordered in accordance to their triggering capacity.

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**Table 6 Criterion Table for Year 2004**

| | RANK 1 | RANK 2 | RANK 3 | RANK 4 |
|---|---|---|---|---|
| S.I / THEME | 4 * WEIGHT | 3 * WEIGHT | 2 * WEIGHT | 1 * WEIGHT |
| Land Use | Agricultural land, Grass land | Degraded forest, Horticulture (or) plantation, Land with or without scrub | Dense forest, forest plantation, Open forest | Village |
| Soil | KG4, KG5 | KG3, KG6 | KG2, KG7, KG8 | KG1 |
| Slope | High Slope | Very Steep Slope | Steep Slope | Moderate Slope |
| Geology | - | - | Charnockite | - |
| Lineament Density | Very High | High | Moderate | Low |
| Drainage Density | Very High | High | Moderate | Low |
| Runoff | Very High | High | Moderate | Low |

**Table 7 Susceptibility Classification**

| Susceptibility Index | Susceptibility Class |
|---|---|
| 0 – 185 | Very High Susceptible Area |
| 185 - 285 | High Susceptible Area |
| 285 - 315 | Moderate Susceptible Area |
| 315 - 400 | Low Susceptible Area |

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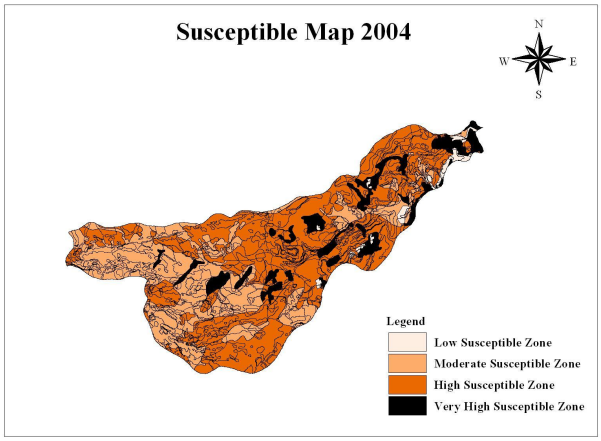


**Fig : 8 Susceptibility Map**

## 4 Results and Discussion

Based on the suitability index the landslide susceptibility levels are classified into four classes. The susceptibility level decreases when the suitability index is high for a particular area. The areas which are susceptible for landslide are calculated as given in the Table 8. The eastern region of the watershed is under high susceptible for landslide whereas the villages in the eastern side are under moderate susceptible for landslide. The dense forest which falls under the western region of the watershed is found to be having moderate susceptibility. The village Sholur is observed as having low susceptible for landslide than other villages. The susceptible maps of the study area are shown in Figure 8.

- The very steep slope is found in eastern region, steep slope is observed in the western region, villages have moderate slope and high slope occurs in agricultural and grass land.
- The horticulture plantation is found as the major landuse in the watershed.
- The watershed is entirely covered by charnockite.
- Majority of the watershed falls under high density category.( drainage density ).
- Majority of the watershed falls under high density category.
- The runoff is high for the entire watershed, with very high runoff in agricultural land which leads to severe erosion. Absence of low runoff is noted in the study area.
- Coarse Loamy Typic Humitropepts and Coarse Loamy Typic Dystropepts were found very high in the central and eastern side of the watershed where slope was very high

**Table 8 Landslide susceptible area**

| Different categories | Area for 2004 ($km^2$) | % of area |
|---|---|---|
| Zone of Very High and high susceptibility | 13.26 | 90 |
| Zone of Moderate Susceptibility | 1.18 | 8 |
| Zone of Low Susceptibility | 0.3 | 2 |

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