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LANDSLIDE SUSCEPTIBILITY MAPPING USING WEIGHTS OF EVIDENCE METHOD IN COONOOR WATERSHED, NILIGIRIS DISTRICT, TAMILNADU, INDIA

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Abstract: *In the present study area, landslides are severely affected mainly due to heavy rainfall. Last three decades, frequent landslides are happen in the Nilgiris district especially in the Coonoor watershed. Weight of evidence method is used for preparing the landslide susceptibility map. In this study area, we are using ten factors associated to landslide. For each thematic layer, weightage has to assign by the interpreter. All the ten causative factors layers are overlaid in the GIS environment and then Landslide susceptibility map has been categorized into five classes based on natural breaks (Jenks) method. In particular, the method can be used for predicting the landslide occurrence area in future. The landslide percentage falling in high and very high landslide susceptibility zones 77.92% indicating that the result from the map is good.*

Key Words: *Landslide, Weight of evidence, and Nilgiris District*

1. INTRODUCTION

India has about 25% of its geographical area under mountainous terrain. The southern, central and western mountains namely the Western Ghats, Sapura and Vindhyan ranges and Aravalis are geologically very old and stable formations as compared to the Himalayas and the Sivalik range in the north. These recent formations are geologically unstable, are in seismic zone and are still in the upheaval stage[1]. Recently, a very rapid increase in the developmental activities in whole Himalaya which comprises of large scale construction of mountain roads, mining activity, overgrazing, deforestation and opening up of steep land for agriculture. The most affected areas are Jammu and Kashmir, Garhwal Himalayas, North East Himalayas, Western Ghats and Nilgiri Hills. For the landslide-hazard assessment, the important steps are collection of data, extraction of relevant parameters from spatial database followed by evaluation of the landslide susceptibility using the relation between the landslide events and landslide causing parameters and validation and results. The key approach of this study is to predict future with the current and past scenarios. In other words, the possibility of occurrence of landslides could be comparable with historic frequency of landslides[2]. The objective of this study is to prepare the landslide susceptibility by recognizing the implications of landslide using Weight of evidence method.

1.1Study area

The Coonoor macro-watershed investigated in the present study (Fig.1) falls in the north-eastern part of Bhavani River Sub-Basin of Tamil Nadu. It lies between Latitudes 11°18'27.42" N - 11°24' 35.426" N and Longitudes 76°41'19" E – 76°53'20" E forming parts of Survey of India Toposheet Nos. 58 A/11/SE, 58 A/15/NW, 58 A/15/SE, & 58 A/15/SW. It covers an area of about 134.9 sq. kms with a maximum length of 22 kms in East – West direction and 12 kms in NE – SW direction. The minimum and maximum altitudes of the watersheds are 340 m and 2600 m respectively above MSL. The macro-watersheds can be divided into four sub-watersheds viz., Upper Coonoor, Upper Katteri, Lower Coonoor and Lower Katteri. The area is selected for study as it is severely affected by landslides. Based on State Groundwater Division, PWD, data for Coonoor station, the watershed receives an average rainfall of 620 mm during the Southwest monsoon from June to August, and the northeast monsoon from October to December record an average rainfall of 280 mm.

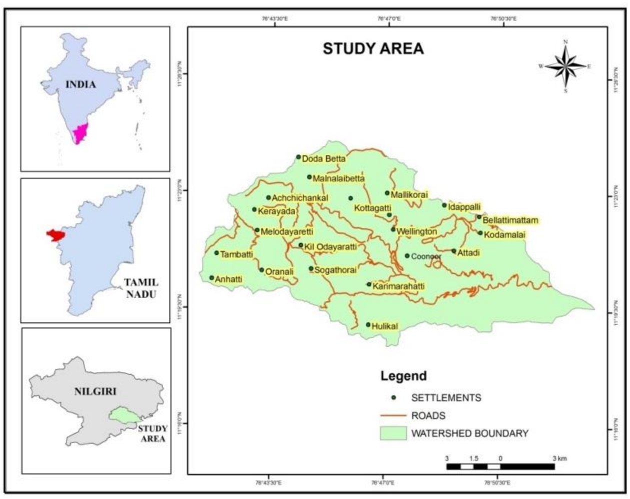

Fig-1: Study area

1.2 Statistical analysis and Interpretation

The landslide inventory map prepared the basis of the method and 102 landslides location taken place in 1978-79 (Source Geotechnical Cell, Department of Geology and Mining, Government of Tamil Nad u) has been used for the present study. For validation of the 77 out of 102 landslides i.e., 75% of the landslide points were used for the analysis and after calculating the landslide susceptibility index and construction of Landslide Susceptibility Map (LSM). In addition to that, the remaining 25 landslides i.e., 25% of the landslides are overlaid on the landslide susceptibility map. The High and Very high landslide susceptibility map class are determined based on the percentage of landslides falling. Higher the percentage of landslides better is the reliability of map. The final LSM will be prepared based on the all landslides. Ten parameters namely slope, aspect, drainage density, distance from drainage, lineament density, distance from lineament, geomorphology, soil, land use, and distance from road were used as causative factors and the influence of the factors were assessed by excluding the same comparing the results with the susceptibility map prepared using all factors.

2. MATERIALS AND METHODS

The landslide inventory layers of the area prepared by the interpretation of aerial photos were scanned and geo-referenced. The landslide locations were demarcated by using of point data in Arc GIS software by validating it with the field visits and surveys. Nilgiris is highly prone to shallow debris which is difficult to recognize due to vegetation cover and deep earth landslides which is Recognized by the paleo scars that is preserved as evidence. One hundred and two landslides had taken place in the Coonoor macro watershed of area 134.9 km^2 during the period of 1978 and 1979. This study integrates various factors such as slope, aspect, drainage density, and distance from drainage, lineament density, distance from lineament, geomorphology, land use, soil and distance from road for generating the landslide susceptibility map.

3. PREPARATION OF THEMATIC MAPS

3.1 Slope

The slope map shows that steep slopes of more than 45 degrees are found in close to the escarpments in the southern part of Lower Coonoor watershed and in the upper part of the Upper Katteri watershed. The map as the histogram shows that the relationship between landslides and slope angle which indicate most of the landslides were observed in the range between 10 to 15 degrees and dominate in all the micro watersheds. In the study area 10 - 15° which covered 18% of the area with 36% of landslides followed by 15 - 25° forms 18% of the area with 29% of landslides, 0 - 10° cover 17% of the area with 20% of landslides, 25 - 35° which forms 16% of the area with 12% of landslides, 35 - 45° covers 16% of the area with 3% of landslides and 45 - 60° which forms 15% of the area with no landslides occurrence. It is observed that most of the landslides occurred within 25° and it is evident that above 25° slopes are restricted to landslides, since the area predominant with barren rocks are exposed

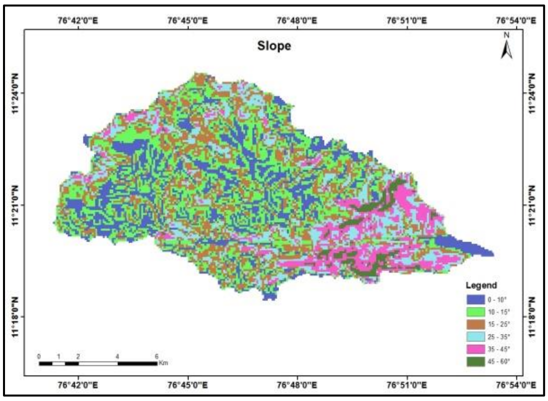

Fig.2 slope map of the watersheds

3.2 Aspect

The aspect map shows that the aspect is controlled by NW-SE trending ridges. The aspect map of the study was categorised into eight classes such as north, northeast, east, southeast, south, southwest, west and northwest with the addition of flat area. Among these flat classes is a horizontal surface. The distribution of landslides also shows that flat slopes have no landslides and southeast aspect have 20% which is the most dominant aspect classes of the study area followed by southwest 19% landslides, south 17% landslides, west 15% landslides, east 12% landslides, northeast 9% landslides, north 6% landslides and northwest 2% landslides. The relationship between the aspect and landslide occurrences in the study area shows that most of the landslides were observed in south facing slopes probably due to precipitation of rainfall more active in south west monsoon.

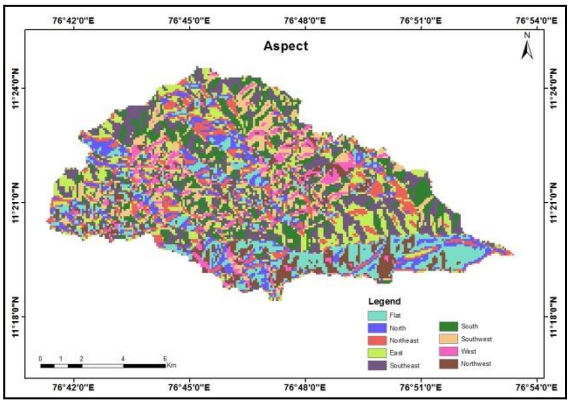

Fig.3. Slope aspect map of the study area

3.3Drainage Density

The drainage density map of the study area shows that the maximum drainage density in the study area is 3.45 km/km2. The higher drainage density occurred in SE part of the area followed by NE. The drainage density categorized in to 5 classes namely very low, low, moderate, high and very high. The moderate class drainage density covers 25% of the area with 27% landslides are dominant in density class followed by low drainage density covers 23% of the area with 23% of landslides, high drainage density covers the area 21% with 24% landslides, very high drainage density covers 16% of the area with 17% landslides and very low drainage density covers 15% the area with 10% landslides.

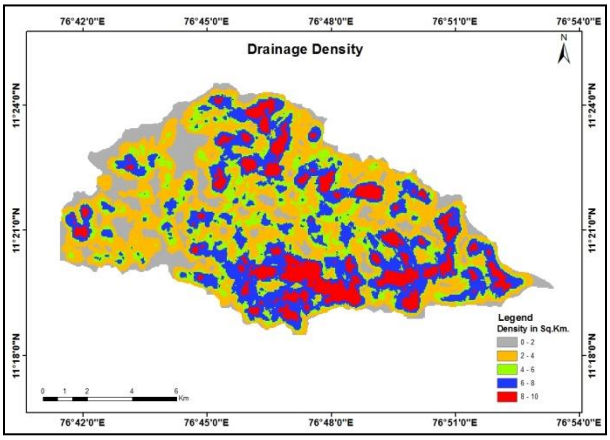

Fig.4 .Drainage map of the study area

3.4 Distance from drainage

The distance to drainage map prepared using spatial analyst tool of ArcGIS. The map subdivided in to five classes viz, 0 -50 m, 50-100 m, 100-150 m, 150-200 m and 200-600 m. Most of the landslides occurred within a distance of 100 m from the streams. These indicate that erosion action of the stream is influencing the landslides and this pattern resultant with drainage density and areas with more streams have more landslides

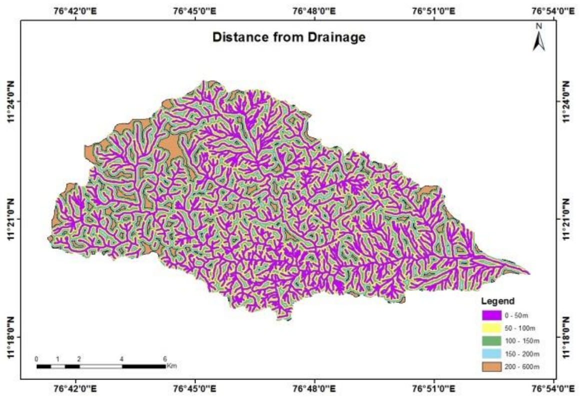

Fig 5 Distance to Drainage map of the study area

The areas with 0 - 50 m class forms 30% of the area with 35% landslides, followed by 50 - 100 m which is 25% of the area with 28% of landslides, 100-150 m which forms 19% of the area with 25% of landslides, 150 - 200 m which is 14% of the area with 7% of landslides and 200 - 250 m class which is 12% of the area with 5% of landslide.

3.5 Lineament density

The lineament density map of the study area grouped into five classes viz., very low, low, moderate, high and very high among these classes, areas with very low lineament density forms 53% of the area with 32% of landslides followed by low lineament density forms 25% of the area with 11% landslides, moderate lineament density forms 8% of the area with 27% landslides, high lineament density which forms 9% of the area with 26% of landslides and very high lineament density which is 5% of the area with 4% of landslides .

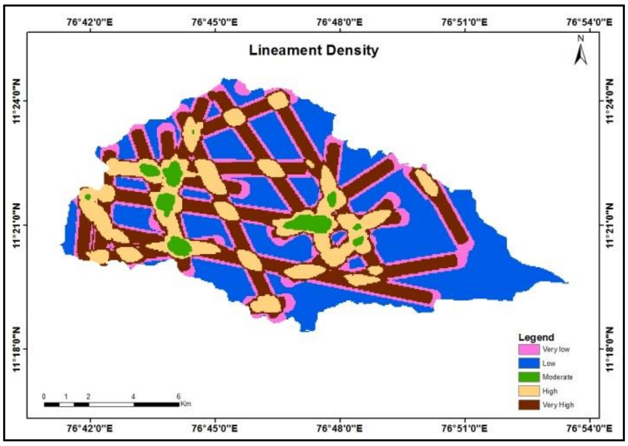

Fig.6 .Lineament density map of the study area

3.6 Distance to lineament

The distance to lineament map prepared using spatial analyst tool of ArcGIS software. The distance to lineament classified into 7 classes with 100 m interval and most of the landslides occurred very near to the streams i.e., less than 100m. The areas with 0 - 100 m class forms 19% of the area with 26% landslides, followed by 100 - 200 m which is 17% of the area with 15% of landslides, 200-300 m which forms 15% of the area with 16% of landslides, 300 - 400 m which is 14% of the area with 11% of landslides, 400 - 500 m class which is 13% of the area with 14% of landslides, 500 - 600 m class which is 12% of the area with 13% and more than 600 m class which is 10% of the area with 5% .The map of the histogram shows that the percentage of landslides higher in the distance ranges between 0 and 100m. The other classes correspond to less number of landslides.

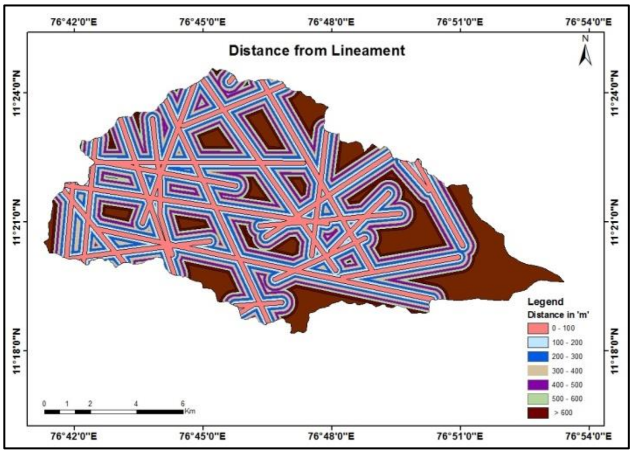

Fig.7.Distance to lineament

3.7 Geomorphology

Geomorphologic factors plays vital role which induces the landslide in the study area. The study area is divided into four geomorphic units such as deflection slope, highly dissected plateau, moderately dissected plateau and valley fills by (Seshagiri et al., 1983). Highly dissected land form is the dominant class followed by, moderately dissected, deflection slope and valley fill. The histogram outlined that highly dissected plateau covers 40% of the area with 69% landslides, followed by moderately dissected plateau occupying 24% of the area with 19% of landslides, deflection slope covers 23% of the area of 8% landslides and valley fills forms 13% of the area with 6% of landslides recorded.

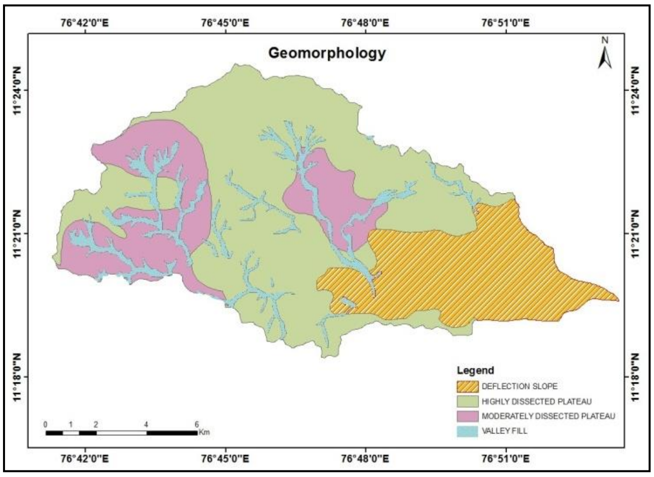

Fig.8. Geomorphology map of the watersheds

3.8 Soil Type

The map of the study area shows that soil has classified in to nine variables namely clay, clay loam, habitation, loam, loamy sand, rock outcrop, sandyclay, sandy clay loam and sandy loam. The most dominant class loamy sand which covers 18% of the area with 45% landslides followed by sandy clay loam forms 16% of the area with 17% landslides, sandyclay covers 17% of the area with 16% landslides, rock out crop covers 10% with 15% landslides, habitation covers 10% of the area with 4% landslides, sandy loam forms 9% of the area with 3% landslides, loam covers 8% of the area with 1% landslides and clay and clay loam covers the area 6% and 5% respectively and not recorded any landslides .

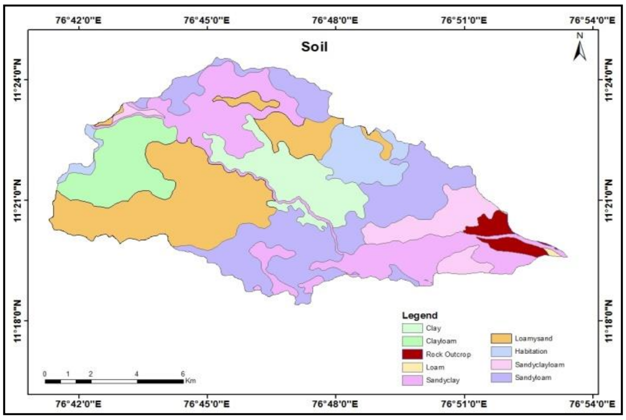

Fig.9.soil map of the watershed

3.9 Land use and land cover

The land use and land cover of the study area classified into nine categories viz., Built-up, crop land, forest, forest plantations, land with scrub, tea plantations, tank bed cultivation, tank bed vegeatation and reservoir. Of these various classes, tea plantation forms 36% of the area with 81% landslides which is major dominant class occurred landslides followed by built-up land covers 9% of the area with 8% landslides, crop land forms 8% of the area with 6% landslides, land with scrub covers 7% of the area with 3% landslides and remaining classes constitute less than 2% of landslides only. Though cultivation of vegetables involves regular disturbance to the lands due to ploughing and irrigation, landslides are less frequent as they are established in areas with gentle slopes by adopting contour cultivation.

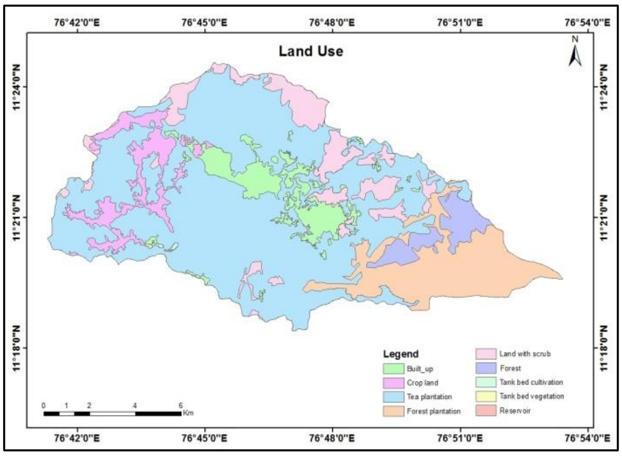

Fig.10. Percentage of landslides and area in each Land Use class

3.10. Distance from Road

Distance from road is similar to the effect of the distance to drainage, occurrence of landslide along road and on the side of the slopes affected by roads.[3][4][5][6] A road constructed along slopes causes reduce in the load on both the landscape and on the toe of slope may develop some cracks. Although a slope is balanced before the road construction, some instability may be observed because of negative effects of excavation. Some landslides were recorded whose origin can be attributed to road construction [7]. Distance from road map was prepared by using multiple ring buffer techniques in ArcGIS spatial analyst tool and is classified 6 classes with 100 m interval and most of the landslides occurred very near to the road i.e., less than 100 m.

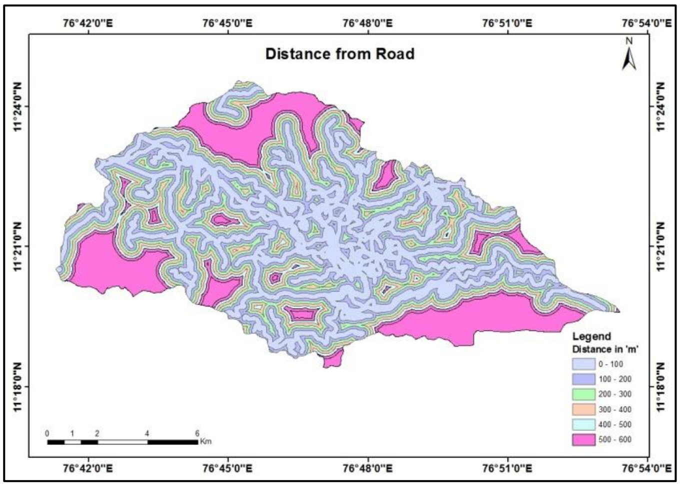

Fig.11. Distance to Road Map of the Watersheds

The map of the histogram shows that the percentage of landslides higher in the distance ranges between 0 and 300m. The other classes correspond to less number of landslides.

4. RESULT AND DISCUSSION

WofE method based on Bayesian theorem was originally developed for gold mineralization researches. Recently, this method also used for landslide susceptibility mapping [8][9]. In this method the weights are measure for each predictive variable is validated by presence and absence of landslides. The positive weight denotes that the landslide event occurs and negative weight indicates that the landslide event does not occur. The difference value is assigned to the variable classes of the landslide related parameters and summation was done as in frequency ratio method. The landslide susceptibility map was prepared by using weight of evidence method and the landslide percentage falling in high and very high landslide susceptibility zones 77.92% indicating that the result from the map is good.

5. CONCLUSIONS

A landslide hazard assessment in Coonoor macro-watershed is the first attempt to prepare the landslide susceptibility map in large scale. The Weight of Evidence methods were used for preparing the landslide susceptibility map and the map shows that the rate of predictable is reliable. The landslide susceptibility map helps to people in practically and cost effective way to identify the areas where the landslides occurred in past or may occur in future. Also, the LSI can be helpful to the state admin for approval of buildings and other major construction and disaster management authorities in mitigation of the hazard. Further, attempt has been made to document the landslide event in 2009. GIS tool used for the preparation of landslide susceptibility maps and the probabilistic analysis yield good results.

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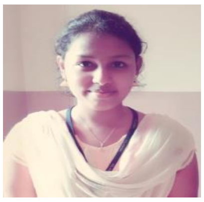

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