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The Assessment and Prediction of Landslide Susceptibility Zonation (LSZ) by Relative Effect Method (Re) and GIS in Coonoor Block, Nilgiri District, Tamil Nadu, India

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Abstract:- **Landslide Susceptibility Zonation (LSZ) is necessary for disaster management authorities to execute proper planning and mitigation measures. In the present study, deploy of Relative Effect (RE) function – a statistical method to incorporate with Remote Sensing and GIS for preparation of LSZ. The present study area is Coonoor block, which is the part of Nilgiri hills and is highly prone to rainfall induced landslides. The various geo environmental thematic maps are prepared such as Geology, Geomorphology, land use and land cover, slope aspect, lineament density, drainage density and soil maps and computed index for each unit geo environmental factors are summed and grouped into five susceptibility classes. The RE method has successful rate of 95.06 % while verifies with existing landslide data and this LSZ is important for disaster management authorities for proper planning in the Coonoor block.**

Key words: Landslide Susceptibility Zonation (LSZ), Causative factors, Relative Effect (RE),

1. INTRODUCTION

Landslides are one of the most vulnerable hazards in the mountainous regions throughout the world. Now days, landslides draw a special attention throughout the world because it causes extensive damages to property and loss of life. Mitigation of landslides can be successfully adopted once detailed study / knowledge that provides the expected frequency and magnitude of landslides that will occur in that area in the near future. Hence, it is necessary to identify landslide prone areas for carrying out speedy recovery, safety migration which would also be very much useful for future planning in the area. In natural hazards, landslides have represented 4.89 % that occurred worldwide every year between 1990 and 2005 (Kanungo et al. 2006). Now this trend is continuously increasing due to unplanned urbanization, development and deforestation activities. Any approach adopted towards Landslide Hazard Zonation (LHZ) requires different conditions which leads to landslides, thematic mapping of these conditions and evaluation of these parameters to landslides.

In India, landslides are one of the most significant hazards that affect the different mountainous region every year during all rainy seasons. Many researchers say that in India, landslides are highly risky at ten hilly states such as Himalayas, North East India, Nilgiris, Eastern Ghats, Western Ghats with including union territory of Pondicherry (Mahe) which causes wide spread damages to thematic mapping of these conditions and evaluation of these parameters to landslides Landslide Hazard Zonation (LHZ) is being carried out by using qualitative and quantitative methods. In the qualitative method, the landslide area is divided into number of zones and expert can assess the hazard prone areas by identifying similar geological and geomorphic conditions in the zones (Ayalew L et al. 2004). In the case of Quantitative methods, statistical, geotechnical and artificial neural network algorithm is employing to evaluate the Landslide Hazard Zonation (LHZ) (Gardiner 1985; Carrara et al. 1991; Mark and Ellen 1995; Gorsevksi et al. 2000a, 2000b; Dai et al. 2001; Lee and Min 2001; Dai and Lee 2002; Davis and Ohlmacher 2002; Suzen 2002; Ohlmacher and Davis 2003; Lee 2005).

Geographic Information System (GIS) is the most powerful tool to evaluate the landslide hazard zonation by incorporation of various thematic maps and field prediction. By Remote sensing and GIS technology, it is highly possible for effective collection of data, manipulation and integrate a variety of spatial data with different causative factors that are responsible for occurrence of landslide in such as geology, structure, surface cover, slope characteristics etc. Integration of these thematic maps in a GIS environment leads to generation of Landslide Susceptible Zonation (LSZ) (Okimura and Ichikawa 1985, Montgomery and Dietrich 1994; Wu and Sidle 1995)

The main objective of the present study is to apply a promising approach to a model with special reference to spatial distribution of rainfall trigged landslides and relative effect of some preparatory (internal) factors and triggering (external) factors to determine the factor of slope instability in a quantitative manner by apply of Relative Effect Function (REF). These landslide susceptible zones are more sensitive environment defined by the establishing quantitative relationship between past landslides and affecting factors by Relative Effect Function (REF) method. In this study, seven internal and external factors such as Geology, Geomorphology, Land use and Land cover, Slope aspect, Soil cover, Lineament density and Drainage density has been taken. These maps would help to explain lessons from the past landslide events and making of emergency decisions to mitigate of future landslides in the study area.

2. STUDY AREA

The study area (Figure 1) is situated in the eastern part of Nilgiri district, located in the western part of Tamil Nadu. The present study area, Mettupalaym to Coonoor Ghat section (NH -181) is coming under the Coonoor Block and falling in the middle of Coimbatore – Pykara National Highways. The Mettupalayam to Coonoor ghat section is with a length of 35 km and the entire catchment area is taken into account to evaluate landslide prone areas. The study area which lies between latitudes 11°19'00"N and 11°23'00"N and longitudes of 76°47'00"E and 76°54'00"E and covers an area of 40.34 Km^2 approximately. This study area falls in the survey of India toposheets (1:25000) 58 A/15 SE and 58 A/15 SW.

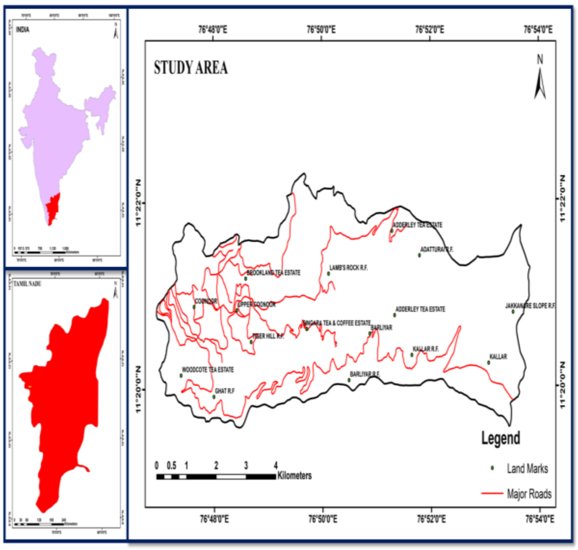

Figure 1: Location Map of the Study Area

In the study area, the minimum and maximum altitudes are 327m and 2091 m above the mean sea level respectively. This Ghat section is also called as "Kallar Ghat Section" which follows the valley of Kallar and Coonoor River. The study area receives an average rainfall of 1435.73 mm during South West monsoon and 2934.07 mm during North East monsoon. The average annual Rainfall recorded in the study area is 2184.90 mm. The rain fall pattern is seasonal and maximum expected at the month of October to December.

3. METHODOLOGY

The landslide susceptibility analysis is carried out by using different resulted layer maps which are derived from various sources and techniques. The Landslide Susceptibility Zonation can be evaluated from various thematic maps through compilation of different database. The compilation of database is consisting of three important processes. a) Digitization and data correction for modification of old data information, b) Extraction of information from satellite imageries, aerial photographs and c) Detailed field survey for validate the thematic maps. The fundamental database is derived from Survey of India (SOI) toposheets (1:25000 scale), aerial photographs, and IRS LISS – III satellite imagery. In the meantime, extensive field work is carried out in the entire study area for collection of various information such as landslide locations, slope characteristics, geometrical analysis of each individual landslide points and thickness of soil cover. Field verification is also done for validating of land use and land cover in the study area. The entire spatial database constructed by using GIS techniques, where different layer maps are prepared by using field information such as geology, geomorphology and soil cover. Slope aspect, elevation, 30 m contours, drainage map and geomorphology units are extracted from DEM 30 m resolution data base. The land use and land cover map is derived from IRS-ID LISS –III satellite imagery, aerial photographs, google maps, and NRSC Bhuvan maps, whereas the lineament map is extracted from the aerial photographs and satellite imageries.

In the present study, slope instability is quantified by introducing a new method called "Relative Effect" function. The landslides caused by internal and external factors which are derived from various sources and thematic maps are prepared for overlay analysis between landslide point and individual thematic maps. The relative effect is calculated from the following formulasIn general Ɛ values are positive near to zero.

There are three important criteria deciding RE of the each units

1. RE is less than zero that means the share points of a unit landslides is less than its share in area coverage. This means effect of landslide risk is decreasing trend. It is also called as "Negative Effect".
2. RE is more than zero that means the share points of a unit landslides is more than its share in area coverage. This means effect of landslide risk is increasing trend. It is also called as "Positive Effect".
3. RE is zero that means the share points of unit landslides more or less equal to its share in area coverage. This means, there is no effect of landslide risk is decreasing or increasing trend.

Whereas α is zero if there is no landslides; otherwise α is equal to 1. The higher positive value of slide risk indicates a higher risk of landslides and negative values indicates of low risk of landslides.

3.1 Geology

The Mettupalayam to Coonoor ghat section is coming under Coonoor block which is the part of Nilgiri ranges. Our study area composed of bulk metamorphic rock unit (High grade of metamorphism) of Archaean age rock unit called "Charnockite". Charnockite is hypersthenes bearing quartzo-feldspathic granulite which appears in dark colour basement rock. At present, this Archean rock is coming under "Sargur Schist" (Figure 2).

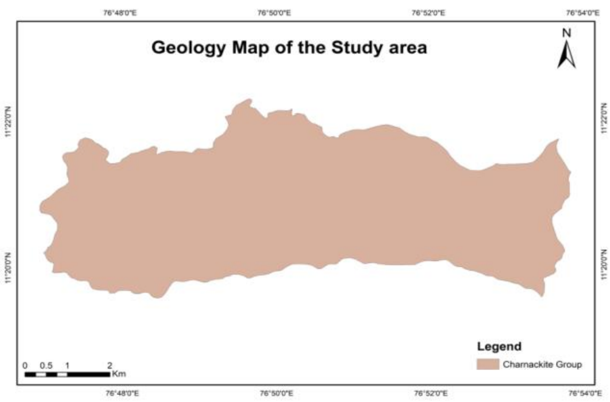

Figure 2: Geology Map of the Study Area

3.2 Geomorphology

The study area is an active, young mountainous terrain. In the valley sides, tributaries extend from valley towards main distributaries which connects to Coonoor River. The study area is uneven topography with highly dissected by many ridges and valleys. Coonoor River flows West – East direction in the study area and having V shaped valleys with steep gradient and high run off. This entire area is dominated by denudational highly dissected hills and eastern part is covered with denudational pediment and fluvial origin Bajada (Figure 3). Field verification is also done for validating of land use and land cover in the study area. The entire spatial database constructed by using GIS techniques, where different layer maps are prepared by using field information such as geology, geomorphology and soil cover. Slope aspect, elevation, 30 m contours, drainage map and geomorphology units are extracted from DEM 30 m resolution data base. The land use and land cover map is derived from IRS-ID LISS –III satellite imagery, aerial photographs, google maps, and NRSC Bhuvan maps, whereas the lineament map is extracted from the aerial photographs and satellite imageries.

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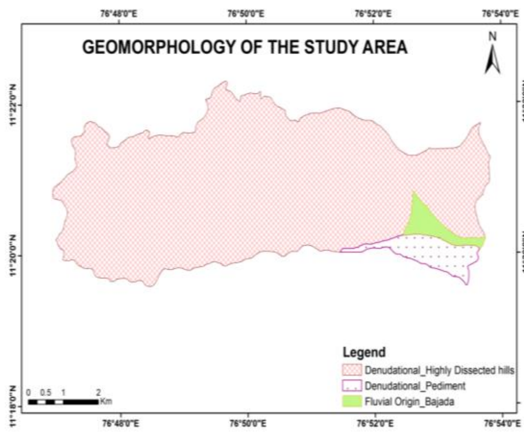

Figure 3: Geomorphology Map of the Study Area

3.3 Soil Cover:

It is necessary to analyse the soil cover in the study area which is the important factor for landslides. The entire study area is made of monolithic soil called "Inceptisols" and occupying 100 % study area (Fig. 4).

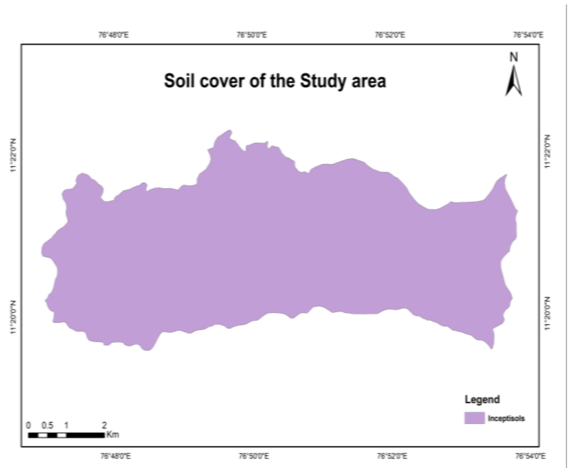

Figure 4: Soil cover map of the Study Area

3.4 Land use and Land cover

Land use and Land cover (LULC) is also one of the important factors responsible for Landslides. Hence, it is necessary to take up a detailed study for potential landslides. The probabilities of landslides occurrences are inversely proportional to vegetation density in the study area. Similarly improper utilization of LULC leads to erosion and weathering which causes instability of slopes. Hence, Barren land and highly build up areas in steep slopes are more prone to landslides than forest areas.

Nine major Land use and Land Cover (LULC) units are identified in the study area such as Agriculture Plantation, Agriculture Crop land, Build up area urban, Build up area Rural, Barren lands, Evergreen forest, Deciduous forest, plantation forest and forest swamp. The final LULC map is prepared through extensive field work as well as lab work to delineate final LULC map (Figure 5).

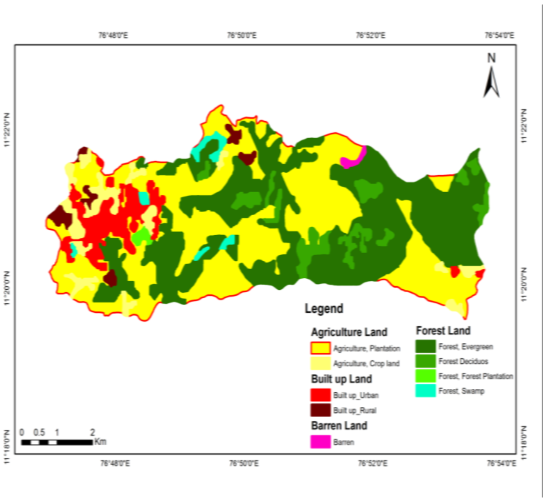

Figure 5: Land use and Land cover (LULC) Map of the Study Area

3.5 Slope Aspect

In the study area, the aspect refers to maximum possibility direction of slope and is divided into ten classes which are N - class I (1-22.5); NE - class II (22.5-67.5); E - class III (67.5-112.5); SE - class IV (112.5-157.5); S - class V (157.5-202.5); SW - class VI (202.5 – 247.5); W - class VII (247.5-292.5); NW - class VIII (292.5 – 337.5); NNW - class IX (337.5 – 360) and flat - class X (0-1) (Figure 6).

Lineament and any Planar structures are important factor for assessing stability of slopes which destabilize the area as well as leads to deterioration of rocks which energize the weathering processes. Lineaments are formed in the various geological stress conditions either by tensional or compressional environments. The lineaments are prepared by visual interpretation of satellite imageries and google maps for identifying of fault line and fractures.

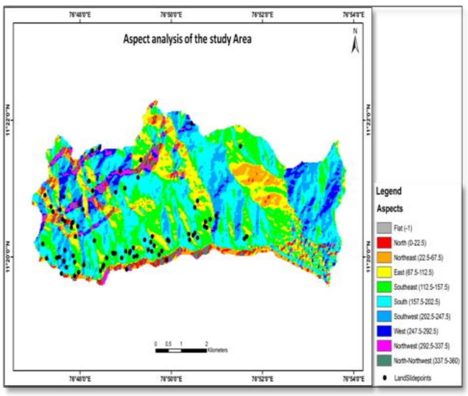

Figure 6: Slope Aspect Map of the Study Area

3.6 Lineament Density

Lineament and any Planar structures are important factor for assessing stability of slopes which destabilize the area as well as leads to deterioration of rocks which energize the weathering processes. Lineaments are formed in the various geological stress conditions either by tensional or compressional environments. The lineaments are prepared by visual interpretation of satellite imageries and google maps for identifying of fault line and fractures. Based upon lineaments, lineament density map is prepared. The lineament density varies between 0 and 7.52. Hence, the Lineament density has been classified based upon natural breaks into 4 categories such as class I (0 – 1.03); class II (1.04 – 2.86); class III (2.87 – 4.49) and class IV (4.5 – 7.52) (Figure 7).

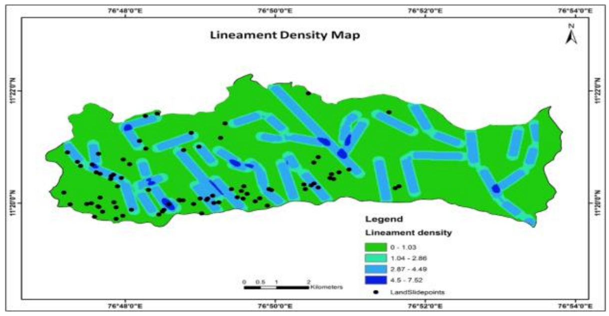

Figure 7: Lineament Density Map of the Study 3.7 Drainage Density:

Type	% of coverage geological units	% of Slide points	Relative Effect function (REF)
Charnockite	100	100	0

Table 1: correlation between percentage of Geomorphic units and Percentage of slide points

It is necessary to analyse the influence of drainage lines on landslides. In mountain areas, the drainage density gives indirectly the information about groundwater condition which cause landslides (Ashis K. Saha et al. 2005: Pradhan et al. 2017). Hence it is necessary to identify the proximity of drainage and the division is based upon natural breaks into 4 categories such as class I (0 – 3080); class II (3090 – 5610); class III (5620 – 7520) and class IV (7530 – 12,400) (Figure 8).

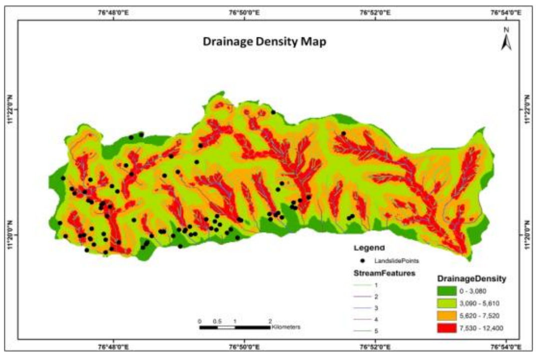

Figure 8: Drainage Density Map of the Study **Area**

Type	% of coverage of soil coverage units	% of Slide points	Relative Effect function (REF)
Inceptisols	100	100	0

Table 2: correlation between percentage of Geological units and percentage of slide

Type	% of coverage of Geomorphic units	% of Slide points	Relative Effect function (REF)
Denudational, Highly Dissected Hills	93.1365	100	0.03088
Denudational, Pediment	4.5087	0	-
Fluvial origin Bajada	2.3549	0	-

Table 3: correlation between percentage of soil coverage and Percentage of slide points

Type	% of coverage Land use and land cover units	% of Slide points	Relative Effect function (REF)
Agriculture, Plantation	43.1107	44.4444	0.0132
Agriculture, Crop land	4.0870	4.9383	0.0822
Built up urban	6.0909	9.8765	0.2099
Built up Rural	1.6473	1.2346	-0.1252
Forest, Evergreen	38.8349	38.2716	-0.0063
Forest, Deciduous	4.6377	1.2346	-0.5748
Forest, plantation	0.3261	0.0000	-
Forest, swamp	0.9976	0.0000	-
Barren Land	0.2677	0.0000	-

Table 5: correlation between percentage of slope aspect coverage and Percentage of slide points

Type	% of coverage of Lineament density units	% of Slide points	Relative Effect function (REF)
0 - 1.03	49.07	59.2593	0.0819
1.04 – 2.86	12.36	14.8148	0.0787
2.87 – 4.49	32.74	23.4568	-0.1448
4.50 – 7.52	5.83	2.4691	-0.3731

Table 7: correlation between percentage of drainage density and Percentage of slide points

Type	% of coverage of drainage density units	% of Slide points	Relative Effect function (REF)
0 - 3080	10.12	11.1111	0.0406
3090 – 5610	29.58	33.3333	0.0519
5620 – 7520	25.24	34.5679	0.1366
7530 – 12400	35.06	20.9877	-0.2228

Table 8: Percentage area of risk classes

Type	% of coverage of slope aspect units	% of Slide points	Relative Effect function (REF)
Flat	0.0185	0.0000	-
North	2.8732	0.0000	-
Northeast	6.8573	7.4074	0.033514
East	11.7583	13.5802	0.062562
Southeast	24.9163	33.3333	0.126396
South	28.5563	19.7531	-0.16007
Southwest	15.2782	18.5185	0.083534
West	5.5131	3.7037	-0.17276
Northwest	2.1918	2.4691	0.051737
N-Northwest	2.0371	1.2346	-0.2175

4. RESULT AND DISCUSSION

The following observations are made from the Relative effect function in the Landslide Susceptibility Zonation (LSZ) map preparation. In the geological units and soil units, the zero values of RE indicates that there is no possibility of landslide due to lithology and soil nature. i.e. lithology and soil cover won't play any vital role in landslides in the study area (Table 1 & 3). A highly dissected hill exhibits more active drainage system which is responsible for landslides (Table 2). In the case of land use and land cover, agriculture plantation, crop land and built up urban land showing positive trend clearly indicates that there is improper utilization of land use, drainage system and population growth play vital role for triggering of landslide in the study area (Table 4).

The slope aspect map exhibits east, south west and west face slopes are highly prone to landslides due to gully erosion more in these directions (Table 5). The low lineament density and low to medium drainage density exhibits possibility of landslides which may be due to in active lineaments and low order streams causes more erosion than higher order streams (Table 6 & 7). By using Relative effect (RE) function, the final landslide susceptibility zonation is prepared. It is clearly is indicating that 20.21% area are coming under Very high hazard, 46.17 % areas are High hazard, 15.08% area are moderate hazard, 5.28% areas are low and 13.25% area are very low (Table 8 & Figure 9).

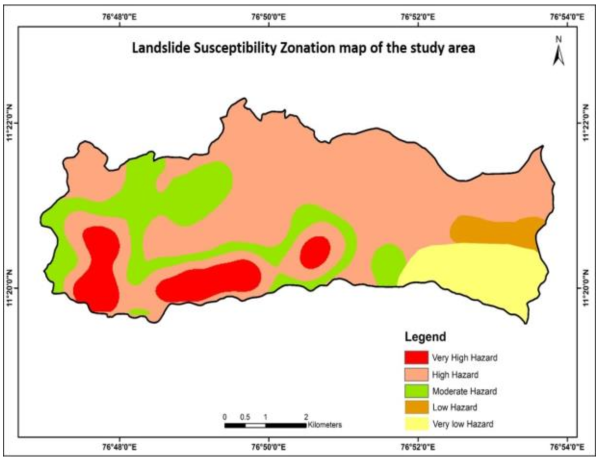

Figure 9: Landslide Susceptibility Zonation (LSZ) Map of the Study Area

The landslide inventory map shows that out of 81 landslide points, 77 points are coming under the high to moderate zones with successful rate of 95.06 %. Similarly the landslide susceptibility map shows that the western part of the study is highly subjected to improper utilization of land use and land cover (urbanisation) and drainage systems.

5. CONCLUSION

From the Relative Effect function, which clearly marks that agriculture plantation, crop land and built up – urban lands show positive values that indicate the high possibility of landslides due to improper utilization of land use and drainage system especially in the agriculture fields or crop lands. Similarly low order streams and low order lineaments are more active and cause landslides in the study area. This present study reveals that nearly 66 % of the study area is coming under the very high to high hazard. The landslide susceptibility map is prepared from Relative Effect (RE) method has successful rate of 95.06 % while verify with existing landslide data, exhibit most satisfactory level. It is clearly evident that incorporation of geomatics and arithmetic methods are powerful tools for landslide studies.

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