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Geomatics Based Landslide Vulnerability Zonation Mapping - Parts Of Nilgiri District, Tamil Nadu, India.

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ABSTRACT
Landslide includes a wide range of ground movements, such as rock falls, deep failure of slope, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide. The Nilgiri Hills (Mountains) of Tamil Nadu, India are prone to landslides, which often result in considerable damage to private property, public infrastructure, and loss of life. The mapping of LVZ includes, the preparation of various thematic layers from different data sources, such as Survey of India topographic sheets, Satellite data, Geological Survey of India maps etc. These landslides are typically the result of the structural failure of thick laterite soils that have been saturated by heavy rains during the monsoon season. . GIS have proved to be useful tools for analyzing and managing landslide related data. GIS has been widely used in quantitative estimation landslide susceptibility. The methodology adopted for the identification of landslide vulnerable zones, and suggestion of remedial measures based on the vulnerability of landslides on different terrain parameters per unit area. Through this study, it is evinced again that the geomatics technology is a proven tool for landslide studies in order to properly understand, identify and suggest remedial measures.
KEY WORDS: Geographical Information System, Satellite Image, Vulnerability Zonation, Lineament Density, Land Use, Land Cover.

I INTRODUCTION

1.1 GENERAL

Landslide is defined as the "the movement of mass of rock, debris or earth down a slope" (Cruden 1996). Varnes (1958) defined landslides as the downward movement of slope forming materials composed of rocks, soil or artificial fills. According to bell (1992), landslide occur because of the forces creating movements exceed those resisting forces. Landslide are frequently responsible for considerable losses of both money and lives, and the severity of the landslide problem worsen with increased urban development and change in landuse. The term landslide includes a wide range of ground movements, such as rock falls, deep failure of slope, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, therefore are other contributing factors:

- Erosion by rivers, glaciers, or ocean waves create oversteepend slopes
- Rock and soil slopes are weakened through saturation by snowmelt or heavy rains
- Earthquake create stresses that make weak slopes fail
- Earthquakes of magnitude 4.0 and greater have been known to trigger landslides
- Volcanic eruptions produce loose ash deposits, heavy rain, and debris flows
- Excess weight form accumulation of rain or snow, stockpiling of rock or ore, form waste piles, or from man-made structures may stress weak slopes to failure and other structures.

The world's mountain lands include regions of unique hazards that pose a threat to human activities and are a huge economic burden on developing countries. Landslides are a frequently occurring natural hazard that increase the vulnerability, and therefore risk, to the lives, properties and infrastructural facilities in the mountain environment. The structurally deformed rocks have been subjected to severe erosion by toe cutting action of deeply dissecting rivers and streams. All these adverse characteristics contribute in making the terrain susceptible to landslide occurrence. Landslide hazard zonation (LHZ) refers to "the division of a land surface into homogeneous areas or domains and their ranking to degrees of actual/potential hazard caused by mass-movement" (Varnes,1984). In the recent past various methods and techniques have been proposed to analyse causative factors and produce maps portraying the probability of occurrences of similar phenomena in future. Broadly these methods can be classified as direct and indirect methods. The direct method consist of geomorphological mapping in which past and present landslide are identified and assumption are made on the factors leading to instability, after which a zonation is made of those sites where failures are most likely to occur. Land hazards are natural process and they become hazardous only when people live or work in areas where these processes occur naturally. The naturalness of these hazard is a philosophical barrier that we encounter when try to minimize their adverse effects. Study of land hazard can be successful only when detailed knowledge is obtained about the geoenvironmental factors, which influence the character, magnitude and frequency of slope failure processes in the area. The zonation of land hazard must be based on the natural and human activity factors. Analysis of land hazard is a complex task, as many factors can play an important role in the erosion processes as also for the occurrence of landslides. The analysis requires a large number of input parameters and is time-consuming. The present study deals with the landslide/ land hazard zonation of study area using remote sensing and geographic information system(GIS) techniques.

1.2 CAUSES OF LANDSLIDES

Landslides can be triggered by natural causes or by human activity. They range from a single boulder in a rock fall or topple to tens of millions of cubic metres of material in a debris flow. They can vary also in their extent, with some occurring very locally and impacting a very small area or hill slope while others affect much larger regional areas. The distance travelled by landslide material also can differ significantly with slides travelling from a few centimetres to many kilometres depending on the volume of material, water content and gradient of the slope.

1.3 ROLE OF REMOTE SENSING IN LANDSLIDE VULNERABILTY ZONATION MAPPING

A number of remote sensing data products are available for the study of Landslides. Remote sensing techniques are well suited for landslide studies as landslide directly affect the ground surface. Landslide information extracted from satellite images are mainly related to the morphology, vegetation and drainage conditions of the slope. The interpretation of landslide from remote sensing data requires knowledge of the distinctive features associated with slope movements and of the image characteristics associated with these features such as color, tone, texture and shape. The interpretability of landslides in an image is influenced by the contrast that results from the spectral or spatial difference that exists between the landslide and its surroundings. For example, landslide debris movement distrupts the vegetation cover and exposes the soil and undergrowth and hence alters their spectral characteristics. Vegetation cover is considered to be a potential factor for landslide identification form remotely sensed data based on its multi-spectral and textural characteristics. Hence vegetation cover and high moisture content in the debris along with their shape and location are used as a key in demarcating the slide areas. The spatial and spectral resolution of the remote sensing data provides the primary control on the interpretability of slope instability phenomena and thus decides the applicability of type of remote sensing data for landslide studies. The IRS-P6 LISS-III satellite data, though good for differentiating the barren land from vegetated land, does not serve the purpose fully to identify the landslide slopes. Satellite data including visible and infra-red bands, offer some unique spectral and spatial information that could useful for landslide related studies, particularly in regional scale analysis.

1.4 ROLE OF GEOGRAPHIC INFORMATION SYSTEM

Geographic information system (GIS) technology assists in integrating information in a way that helps us understand and address some of the most pressing problems we face today such as landslide, deforestation, acid rain, rapid urbanization, natural resource management, forest fires, and floods, etc. it provides a basis for making timely and intelligent decision by helping us to organize data about these problems and to understand their spatial relationships. GIS based techniques are the best approach to the study of landslide susceptibility because they allow the management of several themes concerning instability factors. GIS have proved to be useful tools for analyzing and managing landslide related data. GIS has been widely used in quantitative estimation landslide susceptibility. The capacity of GIS to store, organize and analyze large amounts of spatial and feature attribute data makes it an extremely useful tool for performing spatial analysis.

GIS, along with remote sensing is being increasingly used in resource analysis to help improve landuse and resource management decisions made at all levels of administration spatial and non-spatial data on various aspects such landuse, soils, geology, hydrology, topography etc. need to be analyzed for management decision. Satellite remote sensing provides a convenient means for deriving such data. Multispectral, Repetitive coverage's of earth by satellite give reliable landcover information at various scales and allow landuse maps to be updated very frequently.

1.5 LANDSLIDES INVENTORY

In order to study a landslide, you need to be able to view the size and contrast of the landslide features and the morphological expression of the topography within and around the landslide. Parameters you might be interested in determining are the type of movement that has occurred, the degree of present activity of the landslide, and the depth to which movement has occurred.

1.6 LANDSLIDE MITIGATION

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of a site and by making inquiries to planning and engineering departments of local governments. They can also obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazard potential of a site, built or unbuilt.

1.7 ABOUT THE STUDY AREA

1.7.1 Location

Nilgiri is a hilly district is situated in the northwestern part of the state. It is bordered by the states of Karnataka in the north, kerala in the west and south and by the districts erode and coimbatore of tamil nadu in the north east and south east respectively. Ootacamund is the district head quarters and a very famous hill resort. The study area, which covers an area of 2000 sq.km falling in the southern part of the nilgiri hills, was selected for the present study as it is frequently affected by various geohazards, particularly the landslides. The said area falls in parts of Nilgiri district and covered by the survey of India topographic sheet Nos. 58A/10,11,14,15. the study area is bounded by North latitudes 11º15′ and 11º45′ East longitude 76º30′ and 77º00′. The study area is bounded by pykara town In the north east and emrald in the southeastern part, the River pykara running from the pykara reservoir in the north eastern part. Reservoirs mukuti, Emeraland and avalanche are major reservoir present in the area.

The study area is approachable by metal road from coimbatore via Ootacamund. In the northern part of the study area the NH67 (Nagapattinum gudalur road) passes through. The other areas are covered by metalled and unmetalled ghat roads. Coimbatore is well connected with Chennai by road, rail and air.

1.7.2 Geology of Study Area

The nilgiri district exposes Charnockite group of rocks with associated migmatites and Bhavani group. The charnockite group is represented by charnockite and pyroxene granulite and covers a major part of the district in the southern part. Which is popularly known as nilgiri massif". The Bhavani group (peninsular gnessic complex) comprise fissile hornblende biotite gneiss and occur in the northern part of the district.

1.8 DATA USED

Satellite data

- ❖ IRS P6 LISS-III (23.5m Resolution)
- ❖ ETM Satellite Data (30 m)
- ❖ SRTM data (90m Resolution)

Ancillary data

- ❖ Survey of India (SOI) Toposheet No:58A10,11,14,15
- ❖ Geological map published by GSI
- ❖ Literature and maps

Software used

- ❖ Arc GIS 9.3.1
- ❖ ENVI 4.3.1
- ❖ ERDAS IMAGINE

1.9 AIM AND OBJECTIVE

The main aim and objectives of the present project are to prepare landslide vulnerable zonation map on 1:50,000 scale for parts of nilgiri hills, tamil nadu, India using the landslides per unit area method in conjunction to SOI toposheet, collateral data, ground truths involving and

- To identify the landslide Vulnerability zones through Landslide distribution data model (Landslide incidence per unit area method) in Parts of Nilgiri district.
- Validate the Identified landslide Vulnerability zones
- Identify the causative factors in such zones and assigning suitable mitigative measures

1.10 SYNTHESIS

The Nilgiri mountain is one of the major mountain systems facing the onslaught of landslides. Infact, it is the third mountain ecosystem in India facing landslides, the other two being Himalayas and the Western Ghats of Maharastra. It is a popular hill resort and in addition a major Tea producing area too. Every year during the monsoons, chain of landslides occurs totally disrupting the intra transport systems as well as it's linkage with other parts of the country. The scientists have been employing various methods all along to prepare landslide vulnerability zonation maps. But no comprehensive and fool proof method is yet to be evolved for LVZ mapping.

So, the present research study has been under taken to evolve a suitable LVZ mapping method by using landslides per unit area method and to validate the Identified landslide Vulnerability zones and finally identify the causative factors in such zones and assigning suitable mitigative measures.

II METHODOLOGY

2.1 LANDSLIDE DISTRIBUTION DATA MODEL (LANDSLIDE INCIDENCE PER UNIT AREA METHOD)

The methodology adopted for the identification of landslide vulnerable zones, and suggestion of remedial measures based on the vulnerability of landslides on different terrain parameters per unit area is given. There are 6 important steps involved in this method, they are:

1. Generation of GIS data bases on various geosystem parameters such as Lithology, Lineament Density, Drainage Density etc.,
2. Deriving the weightages
3. Assigning the weightages
4. Data Integration and Landslide Vulnerability Zonation Mapping
5. Validation and
6. Finally Suggest the suitable remedial measures

The mapping of LVZ includes, the preparation of various thematic layers from different data sources, such as Survey of India topographic sheets, Satellite data, Geological Survey of India maps etc. calculation and assigning of weightages based on the landslide incidence per unit area method (50 landslides) over different inducing parameter layers and GIS integration of all the layers. After this, the resultant LVZ map is validated with another 25 known landslides. Finally suggested the suitable remedial measures for Very high and High landslide vulnerability zones with corresponding to each terrain parameters.

The detailed methodology which was adopted for the present study for identification of landslide vulnerable zonation mapping is given in the following flow chart.

2.1 SYNTHESIS

Natural disasters / geo hazards have become fast spreading epidemics all over the world. In mountainous regions, the landslides is one of the dominant geo hazards. Various techniques are being followed for preparing Landslide Vulnerable Zonation maps. Duly capitalizing the virtues of Remote Sensing and GIS, a demonstrative study has been done for parts of Nilgiri hills, The peer reviewing of the above studies carried out by various scholars in different parts of the world as well as in our country has given in-depth knowledge on the processes and mechanics, controlling parameters and their contribution, various methodologies of mapping of such geohazards and finally the mitigation strategies. Accordingly the technological gap areas were identified and the present research methodology was carved out to bring out comprehensive information on the above geohazards.

III ENERATION OF GEODATABASE ON LANDSLIDE INFLUENCING PARAMETERS

3.1GENERAL

Landslide hazard zonation and their mitigation need various terrain parameters that affect directly or indirectly slope failure process. Therefore ,it is essential to simulate real ground conditions in the GIS environment. Hence, the present study started with generation of database on landslide influencing variables like Base map, geology, structure, lineament, lineament density, geomorphology, drainage, drainage density, slope , Active passive slope, land use / land cover.

3.2 THEMATIC MAP PREPARATION

Thematic map is “specific purpose map” which contain information about a single theme or subject. The themes may be qualitative or quantitative. For the present study areas various thematic maps have been prepared. They are lithology, lineament, lineament density, geomorphology, drainage, drainage density, slope, active and passive slope, soil, land use and land cover. These are prepared at 1:50,000 scale by following the technique of visual interpretation with use of interpretation key elements such as tone, texture, size, shape, associated features.

3.3 BASE MAP

Base map is prepared by using the SOI Toposheet No 58A/10,11,14,15. the base map includes major settlements, major roads, River, Tanks and hill boundary. Roads were taken from Toposheet and are checked with satellite imagery. Gunoor and Otacamund is the two major cities. Study area is containing in major river of moyar river (Figure.3.1).

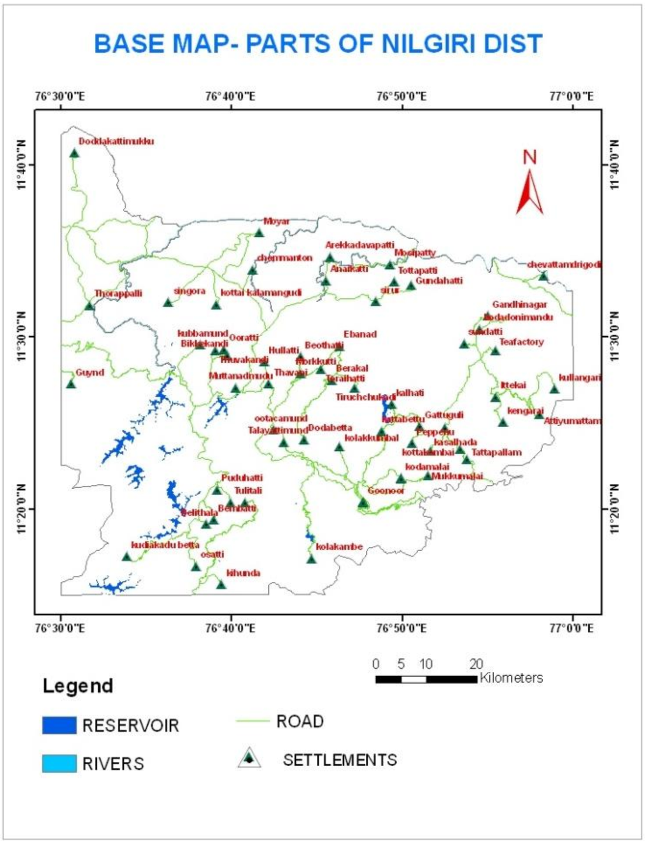

Figure 3.1 . Base Map

3.4 LITHOLOGY

Lithology map was prepared at 1:50,000 scale using geology and mineral resource map of tamil nadu. The main rock types exposed in the area were only charnockite and much of lithological variations were observed either by the earlier workers or in the present study. The study area associated rocks are Hornblende Biotite gneiss, pyroxene granite, dolerite, Ultramafic complex, magnetite quartzite, charnockite.

3.5 LINEAMENTS

Lineaments are linear, Rectilinear and curvilinear features to tectonic origin. They are identified in the satellite imagery through Tonal linearities, Textural linearities, Drainage linearities, Relief linearities, Vegetative linearities

3.6 LINEAMENT DENSITY

The lineament density was prepared from the density tool available in the Spatial Analyst extension of Arc GIS and the same was classified into 5 categories such as Very high density , High density ,Moderate density, Low density, Very low density

3.7 DRAINAGE

The Plateau, nearly co-terminus with the Nilgiri district, is drained by hundreds of streams. The major ones are the Bhavani, Moyar. The original consequent draninage has been superposed by a subsequent pattern as a later development, at places. The catchment for the drainage towards the north is larger in area compared to those of the easterly and south east drainage ages. The drainage is radial in many places due to the dominant high points (Doddabetta, nilgiri peak, mukurti peak etc.) The drainage is influenced mainly by the joint patterns and the foliation trends straight courses in the north east, north west and east directions.

3.8 DRAINAGE DENSITY

The drainage map was prepared from the traced out drainage by measuring the total length of lineaments in square kilometers. The drainage density map is classified in to five categories based on the range of values. Very high density ,High density ,Moderate density ,Low density ,Very low density

3.9 GEOMORPHOLOGY

Geomorphic mapping involves the identification and characterization of the fundamental units of the landscape. A geomorphic unit is defined as an individual and genetically homogenous landform produced by a definite constructional and destructional geomorphic process. Each part of the land surface is the end product of and evolution governed by parent geological material, geomorphic units and their process in an area is very useful in evaluation planning and management of the land resources, environmental planning and developmental activities .The remote sensing techniques have become the most efficient tools for geological, structural, geomorphological studies and their mapping because of its synoptic view Multispectral, multi temporal capabilities. The geomorphic units have specific set of characteristics that determine its image signature. High resolution satellite data provides reliable source of information of delineate and generate comprehensive and detailed inventory of geomorph ic units in an area . The major geomorphic units identified from the satellite image of the study area by visual interpretation technique are Dissected upland, Barren plateau, Barren valley , Valley fill, Undissected plateau, Dissected plateau, Inter montane valley, Reservoir, Composite slope.

3.10 SLOPE

Slope is one of the important factors controlling inducing landslides. The degree of slope controls the extent and speed of the movement of the landslide materials too. The debris moves very rapidly on steep and moderate slope are the chief areas of instability. In general, investigations so, using the advanced virtues available with GIS technologies, slope map was prepared. In the same, the following two different slopes categories were mapped and GIS database was generated .

- ❖ Active-passive slope and
- ❖ Steep-Moderate-shallow and Rolling slope

3.10.1 Active and Passive Slope *(based on Vegetation)*

Active and passive slope were mapped using the LANDSAT –ETM data with the help of the vegetation cover over these slope faces. Wherever more vegetal cover was there, those areas were mapped as passive slope and considered as least susceptible to landslide and barren rocky slope were marked as active slopes, it was checked with Toposheet.

3.10.2 Steep, Moderate, Shallow and Rolling Slope *(based on Inclination)*

Many geoscientists have observed that the areas of steep and moderate slopes are zones of more instability and obviously steep slopes combined with deforestation will be highly vulnerable to landslides. Hence in the present study, the slope of the area were classified into steep, moderate, shallow and rolling slope on the basis of degree of inclination using survey of India Toposheet, the area was fragmented into four categories..

- ❖ Steep (<2mm)
- ❖ Moderate (2mm-4.4mm)
- ❖ Shallow (4.4mm-28mm)
- ❖ Rolling slope (28mm)

3.11 LANDUSE AND LAND COVER

Land use refers to "man's activities and various uses which carried on land" land cover refers to "natural vegetation, water bodies, rock/soil, artificial cover and other resulted due to land transformation. Land use classification of the specified area using remotely sensed data can provide valuable information on the interrelationship between land use and land cover. Landuse and land cover map was prepared by IRS-P6 LISS-III data. The resolution of 23.5 m. The following land use / land cover features were interpreted from the study area were Buit- up land, Tea plantation, Open forest, Dense forest, Evergreen forest, Forest Blank, Dense scrub, Open scrub, Barren rocky , Reservoir

3.12 SOIL MAP

Soil map is prepared from the geological survey of India map. The study area is covered into three types of soil such as clay soil, sandy loam and clay loam

3.13 SRTM MAP

The SRTM map was prepared from SRTM (Shuttle Radar Topographic Mission) of 90m spatial resolution data and elevation ranges from 302m to 2629mts .

3.14 DEM WRAPPED FCC

The Digital elevation map of study area was derived from the ETM and SRTM data. The geomorphological features such as Escarpment, Debris slope and dissected plateau is clearly visible to this map.

3.13 SYNTHESIS

As the present study is aimed at developing mitigation strategies for landslide, the different influencing controlling parameters were mapped and GIS data base were generated for lithology, lineaments, lineament density, geomorphology, Active-Passive slope, Slope (the integrated slope was developed by classifying the slope in to various classes on the basis of vegetation, degree of inclination, morphological expression, level of dissection and were subsequently integrated using GIS to bring out the final finer resolution integrated slopes) steep-moderate shallow Rolling slope Landuse and land cover for further Analysis.

IV DATA INTEGRATION AND LANDSLIDE VULNERABILITY ZONATION MAPPING

4.1 GENERAL

A large database is necessary for the analysis and prediction of Landslides. It needs to be able to store, manipulate and apply the data collected in first two stages (recognition and monitoring). A geographical Information System (GIS) is ideal for this stage in a landslide investigation because it is capable of handling large amounts of past, present and future data and integrating this data with predictions. GIS is capable of data storage and visualization, it is also cheaper and easier to use than a manual map production and overlay. Further, GIS can store and analyze regional databases and therefore perform both local and regional modeling. There are many types of GIS packages which differ in terms of hardware requirements, potential of spatial functions, efficiency of the database, and internal data structure.

4.2 DERIVATION OF WEIGHTAGE FOR LANDSLIDE INFLUENCING PARAMETERS

Derivation of weightages for landslide Vulnerability zonation mapping was carried out by different methods, here the weightages were derived by Landslide incidence per unit area method, for that landslide incidence data is necessary. In spite of mapping out the existing landslide of the whole area(1,860..Sq.Km.), a test site of (202 Sq. Km) was selected due to the constraint of time duration and approachability, the test site represent the maximum heterogeneity of features available in all themes. Detailed field survey was carried out in the test site area to locate the existing landslides and Paleoscars and nearly 75 landslides / Paleoscars are mapped and GIS database was generated. The mapped 75 landslides / Paleoscars are classified into two groups, the first group of 50 landslides are used for analysis to derive the weightage and the next group containing 25 landslides are used to validate the model

After the generation of GIS database on Landslide incidence of the study area, already generated GIS Databases on various terrain parameters numbering over eight, such as Lithology, Lineament Density, Drainage Density, Slope, Geomorphology, Soil and landuse / land cover of the study area were buffered out for the test site. Over these databases, GIS layer having first group of 50 landslides was superimposed independently one after the other and number of landslide falling in each classes of each theme were calculated (LS). From the same, the Landslides per Unit Area (LS/A) were also worked out. The same was shown in below tables (Table-4.1 to Table-4.6).

4.2.1 Lithology

Table.4.1 Derivation of Weightages to Lithology classes through Landslide incidence per unit area method

Sl.no	Geosystem	Sub class	Landslide incidence (L.S)	Area of Sub class in sq.km (A)	Weightage (L.S/A)
1.	Lithology	Charnockite	50	202.156111	0.2473

4.2.2 Lineament Density

Table. 4.2 Derivation of Weightages to Lineament Density through Landslide incidence per unit area method

s.no	Geosystem	Sub class	Landslide incidence (L.S)	Area of sub class in sq.km (A)	Weightage (L.S/A)
1.	Lineament density	Very low	3	20.223564	0.148342
		Low	41	102.167018	0.401304
		Moderate	3	64.030187	0.046853
		High	2	12.893214	0.15512
		Very high	1	2.842128	0.351849

4.2.3 Drainage Density

Table.4.3 Derivation of Weightages to Drainage Density through Landslide incidence per unit area method

Sl.no	Geosystem	Sub class	Landslide incidence (L.S)	Area of sub class in sq.km (A)	Weightage (L.S/A)
1.	Drainage density	Very low	2	14.062449	0.142223
		Low	16	94.899715	0.169599
		Moderate	30	81.857929	0.366489
		High	2	11.336018	0.176429

Slope

Table.4.4. Derivation of Weightages to Slope classes through Landslide incidence per unit area method

Sl.no	Geosystem	Sub class	Landside incidence (L.S)	Area of sub class in sq.km (A)	Weightage (L.S/A)
1.	Slope	Active slope	6	83.45958	0.071891
		Passive slope	44	118.696531	0.370693
		Steep Slope	46	114.998069	0.400007
		Moderate Slope	1	51.760185	0.01932
		Shallow Slope	0	17.497929	0
		Rolling Slope	3	17.899928	0.167598

4.2.4 Geomorphology

Table. 4.5 Derivation of Weightages to Geomorphology classes through Landslide incidence per unit area method

Sl.no	Geosystem	Sub class	Landslide incidence (L.S)	Area of sub class in sq.km (A)	Weightage (L.S/A)
1.	Geomorphology	Dissected upland	29	104.445519	0.277657
		Barren plateau	0	9.66394	0
		Barren valley	3	12.574989	0.238569
		Dissected plateau	16	59.255111	0.270019
		Valley fill	2	16.216553	0.123331

4.2.5 Landuse / Land Cover

Table. 4.6 Derivation of Weightages to Landuse / Land Cover classes through Landslide incidence per unit area method

Sl.No	Geosystem	Sub class	Landslide incidence (L.S)	Area of sub class in sq.km (A)	Weightage (L.S/A)
1.	Landuse and Land Cover	Barren Rocky	1	7.331654	0.136394
		Built up	3	8.163433	0.367492
		Dense forest	0	33.15263	0
		Dense scrub	1	11.06360	0.090386
		Evergreen forest	7	81.95818	0.085409
		Forest Blank	0	13.58698	0
		Reservoir	0	0.310894	0
		open forest	33	7.687410	4.292733
		open scrub	5	38.901317	0.128530

4.2.6 Soil

Table. 4.7 Assigning of Weightages to Landuse / Land cover classes through Landslide incidence per unit area method

Sl. No	Geosystem	Sub class	Landslide incidence (L.S)	Area of subclass in sq.km (A)	Weightage (L.S/A)
1	Soil	sandy loam / Red soil	2	30.417667	0.065751
		clay soil	48	171.738444	0.279494

4.3 ASSIGNING WEIGHTAGES FOR LANDSLIDE INFLUENCING PARAMETERS

The above derived weightages (shown in last column of the above tables (L.S/A) were assigned to the individual classes of corresponding themes of a test site and weightage assigned vector layers are convert in to weighted Raster layer based on the weightages.

4.4 GIS INTEGRATION

The main purpose of various data integration techniques or models is to combine spatial data from diverse sources together to describe and analyze interactions, to make prediction with models, and to provide support to decision makers. In this regard, two important assumptions made are as follows:

1. The occurrence of past landslides in the area is dependent on parameters taken as input geo-scientific data.
2. The future landslide will occur under similar conditions in which the past landslides have occurred.

Geographical Information System (GIS) plays an increasing role in the analysis of landslide hazard zonation, as it offers map overlaying possibilities and calculation facilities far superior to conventional techniques. It is an important tool in evaluating the accuracy of the input data. One of the major contributions of GIS may be the reduction of the subjective element during the analysis phase, allowing the user to concentrate more on reducing errors stemming from the input data. It is especially useful in those situations where the causal factors for mass movements are not fully understood. The user can test hypotheses rapidly, and select the most important combination of factors by trial and error. In order to generate the Landslide Vulnerable Zonation map for the present study area, the weighted Raster layers of the test site such as Lithology, Lineament density, Drainage Density, Slope, Geomorphology and Landuse/ Land cover were integrated together using the raster calculator menu of the Spatial Analyst extension module of the Arc GIS. Thus the integrated GIS layer having accrued the total weightages of all the 8 layers which ranged ranging from 0.8125 to 6.6356 as shown in (Figure.4.1).

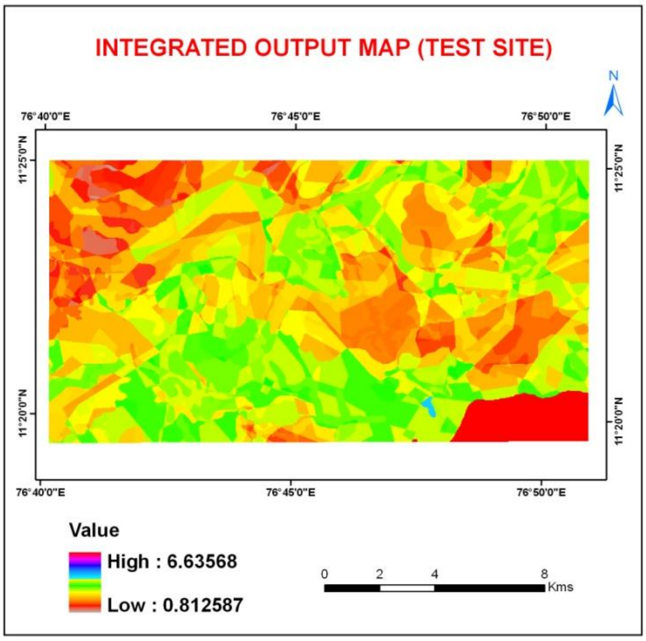

Figure 4.1Integrated Map (Test Site)

This dynamic range was regrouped in to 5 classes of landslide vulnerability viz:

- Very Low Vulnerable Zone (0.8125 – 1.4976)
- Low Vulnerable Zone (1.4976 – 1.7260)
- Moderate Vulnerable Zone (1.7260 – 1.9315)
- High Vulnerable Zone (1.9315 – 2.2283) and
- Very high Vulnerable Zone (2.2283 – 6.6356)

and such regrouped landslide vulnerability map of the test site generated there from is shown in (Figure.4.2).

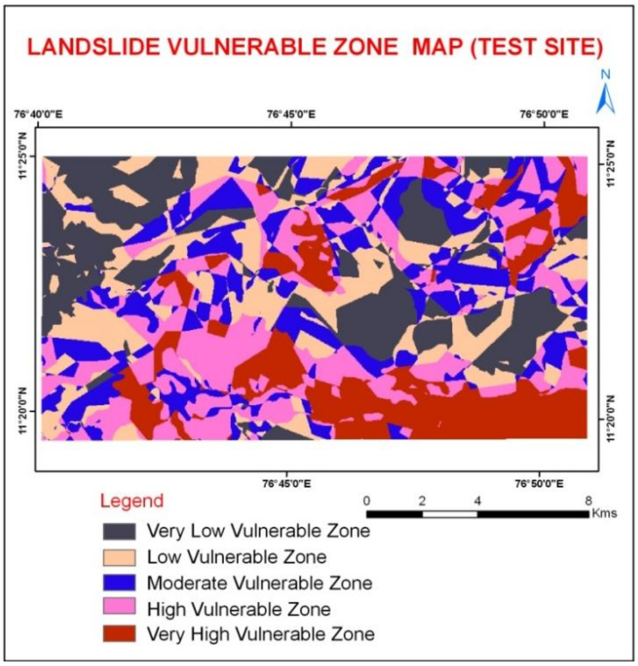

Fig 4.2 Landslide Vulnerable Zone Map (Test Site)

4.5 VALIDATION OF LANDSLIDE VULNERABLE ZONES

For validation, the second group of Landslide incidence map having 25 numbers are superposed over the Landslide Vulnerability zonation map having 5 Vulnerability zones and identify the Number of landslides falling in each classes, it shows that most of the landslides (16 nos.) are falling in Very High Vulnerability zones followed by High Vulnerability zones (5 nos.) and Moderate Vulnerability zones (4 nos.). There are no Landslides are falling in Very Low and Low Vulnerability zones. The same was tabulated and shown in Table- 4.8.

Table. 4.8 Landslide Vulnerable Zones Vs Landslide Incidence

Sl.N0	Landslide Vulnerable Zones	No. of Landslide Incidence
1	Very Low Vulnerable Zones	0
2	Low Vulnerable Zones	0
3	Moderate Vulnerable Zones	4
4	High Vulnerable Zones	5
5.	Very High Vulnerable Zones	16

4.6 LANDSLIDE VULNERABILITY ZONATION MAPPING FOR ENTIRE STUDY AREA

Validation of the landslide vulnerability zones of the test sites shows that the method is suitable for the study area, so the same method extend to the entire study area by assigning the same weightages to the classes of the individual themes and converted in to weighted raster layer.

The weighted raster layers are shown in Figure 4.3 below. The weighted raster layer of the entire area were integrated together using the raster calculator menu of the Spatial Analyst extension module of the Arc GIS. Thus the integrated GIS have accrued the total weightages of all the 8 layers which ranged ranging from 0.8125 to 6.6356, as shown in (Fig. 4.20) This dynamic range was regrouped in to 5 classes of landslide vulnerability viz:

- Very Low Vulnerable Zone
- Low Vulnerable Zone
- Moderate Vulnerable Zone
- High Vulnerable Zone and
- Very high Vulnerable Zone

and such regrouped landslide vulnerability map of the entire area was shown in (Fig. 4.3)

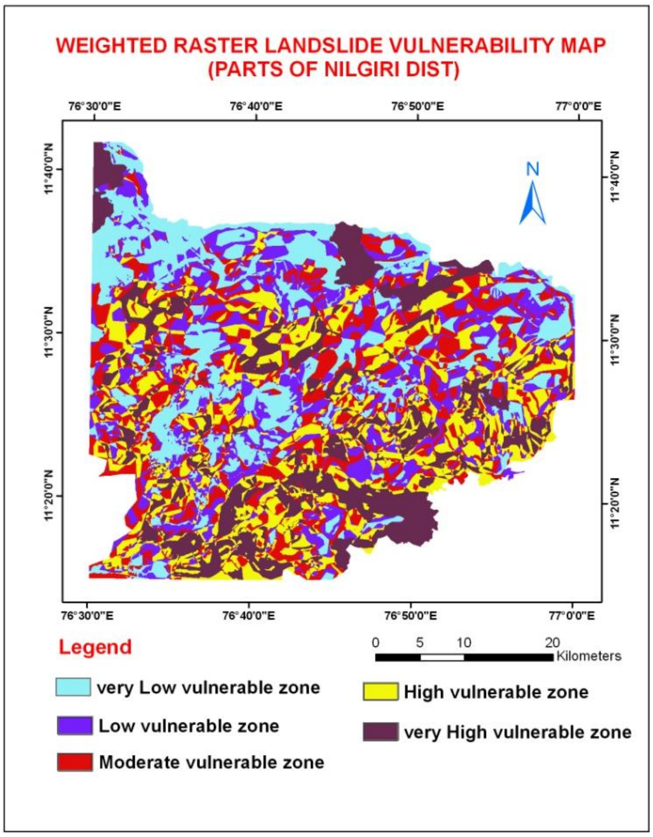

Fig 4.3 Landslide Vulnerability Map (Parts of Nilgiri Dist)

4.7 REMEDIAL MEASURES

The landslide incidence per unit area method has unique credential to show the types of controlling terrain parameters loaded in each polygon / land segment. Accordingly, suitable remedial land management plans can be precisely suggested for different polygon classes depending upon the number and types of terrain parameters. GIS has unique virtues in identifying the actual terrain parameters loaded in each polygon / land segment of landslide vulnerability. For example, in most vulnerable zones , there are 2893 combination polygons with added weightages from 0.8125 to 6.6356 holding various terrain parameter's individual classes loading in different combinations. Now depending upon the type of parameters loaded, different type of remedial measures extended for each polygon classes. Such types and combinations of parameters loaded can be brought out and various suitable land management plans suggested are as follows:

Lithology - Geotextiling, Nailing
Lineament loaded - Grounting, Fracture filled
Polygons vegetation
Geomorphology loaded - Intensive afforestation
Polygons
Slope loaded Polygons - Bench cultivation, Retaining
walls with weep holes, Slope
flattening
Land use / land cover loaded - Intensive afforestation
Polygons Afforestation in forest blanks

Now depending upon the combinations of parameters loaded in each polygons / land segments of Very High / Highly vulnerable zones, combined remedial measures can be executed.

4.8 SYNTHESIS

Subsequent to the generation of various landslide influencing parameters, weightages were assigned to each parameter based on the landslide per unit area and integrated using GIS. From the final derived weightages, a map on landslide vulnerable zones was prepared showing the five zones viz:

- Very Low Vulnerable Zone
- Low Vulnerable Zone
- Moderate Vulnerable Zone
- High Vulnerable Zone and
- Very high Vulnerable Zone

The same map was also validated by superimposing over the past 25 landslide location map and identify the segments having multiple combinations of landslide inducing parameters are identified. By duly considering the controlling or influencing parameters, site specific management plans are suggested to control landslides in the form of afforestation, nailing, retaining walls, etc., to turn for the development of hill area.

V CONCLUSION

THE PRESENT STUDY CONCLUDES

The weathered Charnockite along the topographic slopes play a very significant role in causing rock fall, debris fall, debris flow and topple failures. Moderate Drainage Density also plays a very significant in causing landslide vulnerability in these areas. Geomorphologically, the Dissected Upland and Dissected Plateau appears to be more sensitive for landslides in the region. As far as the slope is concerned, the combination of Active + Moderate & Active + steep slopes are more susceptible for landslides. Out of 50 landslides, 41 landslides are falling in Low and 3, 3, 2 & 1 landslides subsequently falling under Very Low, Moderate, High and Very High Lineament density zones. Open forest seems to be more vulnerable for landslides in this area. The final Landslide vulnerability zonation map generated by the integration of eight weighted raster evidential themes shows susceptibility values ranging from 0.8125 (Very low susceptibility) to 2.2283 (very high susceptibility).After Identification of LVZ map, validate the map with second phase of 25 nos. of landslides which are selected through Hawthi's analysis. In validation out of 25 landslides, 16 landslides are falling in Very High and 5 & 4 Landslides subsequently falling in High and Moderate Vulnerable zones. A newer type of Landslides incidence per unit area based geospatial model has been developed from this study to identify and mitigate landslide vulnerable zones. The best results attained by evaluating the geospatial model shows that if the model is developed in support of spatial data along with constant field survey data proved to be a very successful one. Through this study, it is evinced again that the geomatics technology is a proven tool for landslide studies in order to properly understand, identify and suggest remedial measures.

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