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RESEARCH ARTICLE

APPLICATION OF REMOTE SENSING AND GIS FOR LAND SLIDE HAZARD ZONATION OF KADANADU, NILGIRI DISTRICT, TAMILNADU STATE

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ABSTRACT

Landslide is typically defined by a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Landslide hazard results in great loss of life and property. These damages can be avoided if the cause and effect relationships of the events are known. Landslides are frequent and annually recurring phenomenon in the Nilgiri district. High intensity rainfall triggered most of the landslides in the Nilgiri district. As long as landslides occur in remote, unpopulated regions, they are treated as just another denudation process sculpting the landscape, but when occur in populated regions; they become subjects of serious study. The study area Kadanadu is a part of the Nilgiris District located between $11^{\circ}35$ N and $11^{\circ}58$N latitude and between 76° 74 E and 77° E longitude. The study area falls in the Survey of India Toposheets 58A/11, 58A/14, 58A/15, 58E/2, 58E/3 in 1:50,000 scale. It covers an area 398.483sq.km.The present work is an attempt towards application of GIS for landslide vulnerability mapping. Different thematic layers have been prepared such as geomorphology, lineament density, drainage density, slope, soil depth, and land use. The numerical weights of the categories of the factors have been determined using subject knowledge.

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INTRODUCTION

Landslide is typically defined by a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Landslide hazard results in great loss of life and property. These damages can be avoided if the cause and effect relationships of the events are known. A landslide susceptibility map depicts areas likely to have landslides in the future by correlating some of the principal factors that contribute to landslides with the past distribution of slope failures (Brabb, 1984). Landslide hazard is one of the most significant hazards that affect different parts of India every year during the rainy season. It has been observed that 21 States and Union Territory of Pudducherry, located in hilly tracts of Himalayas, N.E. India, Nilgiris, Eastern Ghats, and Western Ghats, are affected by this hazard every year and suffer heavy losses in terms of life, infrastructure and property (Sharda, 2008). Though the Nilgiri and other mountainous areas are known to be susceptible to landslides, occurrences of such magnitude were unknown earlier (Thanavelu and Chandrasekaran, 2008). Landslides are frequent and annually recurring phenomenon in the Nilgiri district. High intensity rainfall triggered most of the landslides in the Nilgiri district. As long as landslides occur in remote, unpopulated regions, they are treated as just another denudation process sculpting the landscape, but when occur in populated regions, they become subjects of serious study. Hazard zonation map comprises of a map demarcating the stretches or areas of varying degrees of anticipated slope stability or instability. The map has an inbuilt element of forecasting and is hence of probabilistic nature. Depending upon the methodology adopted and the comprehensiveness of the input data used, a landslide hazard zonation map be able to provide the aspects of location of occurrence time of occurrence type of landslide extent of the slope area likely to be affected and rate of mass movement of the slope mass (Rajarathnam and Ganapathy, 2006).

Use of Remote Sensing in Landslide

The phenomenon, landslide is affecting the earth's surface, hence it also falls into the research and application areas of both aerial and space born remote sensing. The nature of this phenomenon as it is occurring at the surface of earth lets earth scientists to exploit this fact using remotely sensed data. On the other hand, again the nature of this phenomenon limits the applications, as being dynamic and sometimes being quite small in terms of conservative remote sensing language.

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Furthermore they reveal very small information when they are observed in planar 2-D, however, they contain large amounts of data when explored in 3-D. Basing on this fact the use of stereo-remote sensing products seems to be indispensable, which reveals the true morpho-dynamical features of the landslides. This information provides the diagnostic information regarding the type of the movement (Crozier, 1973). The landslide information extracted from the remotely sensed products is mainly related with the morphology, vegetation and the hydrological conditions of the slope. The slope morphology is best examined with stereographical coverage.

GIS Based Landslide Hazard Zoning Techniques

Recently, the Geographical Information System (GIS) has become an important tool for landslide susceptibility mapping because it provides the various functions of handling, processing, analysing, and reporting geospatial data. An ideal map of slope instability hazard should provide information on the spatial probability, temporal probability, type, magnitude, velocity, run out distance and retrogression limit of the mass movements predicted in a certain area (Hartlen and Viberg, 1988).

Study Area

The geographical area of the District is 2,543 square kilometers, consists of six taluks namely Udhagamandalam, Coonoor, kadanadu Gudalur, Kundah and Pandalur. The up plateau at an altitude of 6,500 feet consists of three Taluks namely Udhagamandalam, Coonoor and Kotagiri while Gudalur Taluk is the oldest plateau at an altitude of 3,000 feet. There are four Panchayat Unions in this District. The four Municipalities are Udhagamandalam, Coonoor, Gudalur and Nelliyalam. The study area Kadanadu is a part of the Nilgiris District located between 11°35 N and 11°58N latitude and between 76° 74 E and 77° E longitude. The study area falls in the Survey of India Toposheets 58A/11, 58A/14, 58A/15, 58E/2, 58E/3 in 1:50,000 scale. It covers an area 398.483sq.km. It has been observed that natural slopes are disturbed due to cutting of roads for construction purposes, prevention of natural drainage and the changing land use pattern are the factors contributing to landslides and landslips.

Geology of study area

The Kadanadu plateau has long been a subject of detailed studies. Based on the geological, structural and geomorphological evidences a number of geologists have put forth different hypotheses for the origin of the Kadanadu plateau. The prevalent view is that the plateau has come into existence due to uplift by block faulting. The other view is that it is a relict feature carved out by erosional processes. Blandford of Geological Survey of India carried out pioneering geological work in the Nilgiris District in 1850's. According to Blanford, the Nilgiris plateau has been formed by three systems of faults along its peripheries. This is based on the prominent steep escarpments. East-northeast faults with down throw to the south-west form the first system of faults. In the Nilgiri district, the lithology is the charnockite group of bedrocks, covered by the ubiquitous red laterite or lateritic soil. This is taken as a common factor for the whole district. Because of its uniform nature, it is not taken in to account for our study

Geomorphology

The landscape builds up through uplift of volcanism. Denudation occurs by erosion and mass wasting, which produces sediments that is transported and deposited elsewhere within the landscape. The geomorphic features identified from the study area are pediments / Pedi plain, plateau, hill's, valley fill, flood plain, escarpment, denuded slope, and slope on Deccan trap. Cauvery River created several of this features through erosion and deposition work of it.

Slope

Slope is a very important parameter in any landslide hazard zonation mapping. In the study area slope varies from 0 to greater than 41 deg. The entire slope contour map was divided in to four categories as follows: 0 to10, 11 to 20, 21 to 30, 31 to 40, > 41deg.

Soil

Soil types vary all across the basin but the red soils are the predominant category of soils followed by black soils. The highland areas which fall in Karnataka have lateritic soils, reddish brown in color. These soils are shallow, acidic to neutral and are fertile, good for agricultural practices. Highlands of Kerala also have red loam soils along with some areas of black soils which are fertile, rich in organic content and because of high nitrogen content are excellent for agriculture.

Aim and Objectives

- Aim is to delineate landslide zones in Kadanadu for planning purpose.
- To delineate the landslide hazard zones using weighted overlay method.
- To develop a spatial database for landslide analysis
- To delineate a landslide zonation map using remote sensing and GIS
- To provide a decision support tool for hazard managers and planners
- Assessing future trends in remote sensing and its implication on Landslide Hazard Zonation (LHZ) mapping.

Methodology & Database

1. The base map is prepared from SOI toposheets with 1:50.000 scales. Drainage, Contour and are digitized and thus the thematic layers are created from the SOI toposheets using Arc GIS software. The soil map is collected from Agricultural Engineering Department, Chennai and geology and geomorphology maps are collected from Geological Survey of India, Bangalore.
2. Contour is used to generate DEM for the study area. (30m)
3. Satellite image IRS LISS-III is used to create land use and land cover map which is processed using ERDAS 2011 imagine software.
4. Based on the Geo-Technical survey of India, weightages and ranking are given to each and every thematic layer created for the study area. After this all the thematic maps created are analysed using overlay analysis.

5. Thus the landslide vulnerability zonation map is prepared for Kadanadu of the ooty.

3.1a.Software used

Arc GIS 10.0, Erdas 2011, Microsoft Excel, Microsoft Word, Microsoft Access

3.1b.Data:-The various data used in the study area are as given below

1.Kadanadu .shp.
2.Satellite imagery (ASTER-1)

RESULTS AND DISCUSSION

The forces exerted by rocks, earth or other debris moving down a slope can be immense and therefore can devastate anything in its path. Therefore, need to identify the potential zones of landslides for better management. A landslide hazard map categorizes a region into zones of varying degrees of stability and would be a useful regional planning tool for future decision making in regional development projects. The present work is an attempt towards application of Weighted Overlay method for landslide hazard mapping. Selection of factors and preparation of corresponding thematic data layers are crucial components of landslide hazard mapping. The factors governing instability in a terrain are primarily geology, slope, slope aspect, rainfall, NDVI and soil. The variables of these factors are grouped into classes according to landslide susceptibility and numerical weights of the categories of the factors have been determined using subject knowledge.

Geology

The Geology map was derived from the Geological Survey of India with the scale of 1:2,50,000. All the rock types are grouped into five classes in terms of weighted overlay evaluation scale as shown in table. Quatzite, Granite, and Magnetite types of rocks are harder than other types in the study area which rated as 1 in rating evaluation scale. Shown in Table no.1

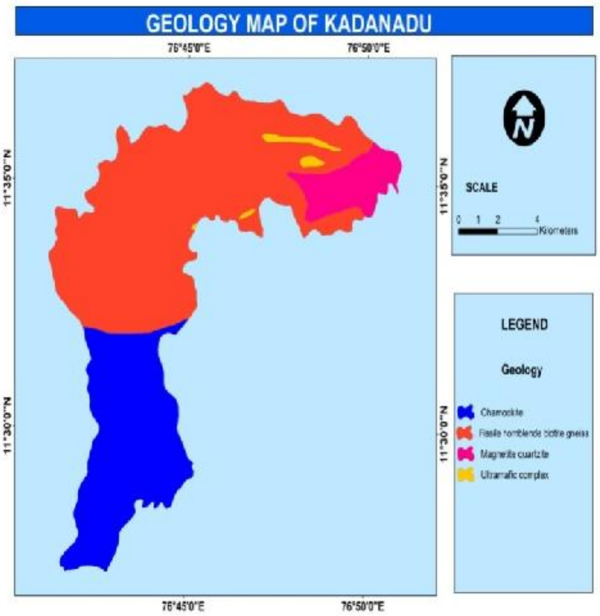


Table 1. Geology Classes

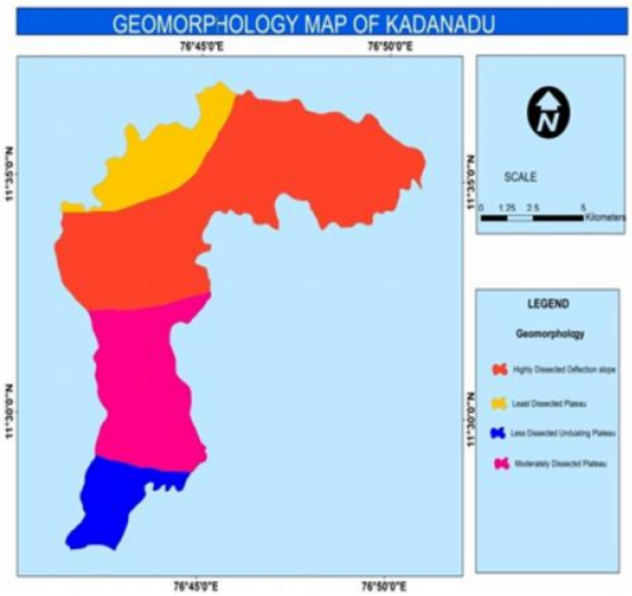
FID	Geology	Weight	Rank	Geowr
0	Chamockite	7	0.3	2.1
1	Fissile hornblende boitite gneiss	7	0.2	1.4
2	Magnetite quartzite	7	0.3	2.1
3	Ultramafic complex	7	0.2	1.4

Geomorphology

The Geological Survey of India toposheets are used to identify the geomorphological features of present study area. The geomorphological features are plateau, alluvial fan, colluvial fills and linear ridges. Listed in Table no.2

Table 2. Geomorphological Classes

FID	Geomorphology	Weight	Rank_1	Morwr
3	Least Dissected Plateau	6	0.2	1.2
2	Highly Dissected Deflection slope	6	0.4	2.4
1	Less Dissected Undulating Plateau	6	0.1	0.6
0	Moderately Dissected Plateau	6	0.3	1.8

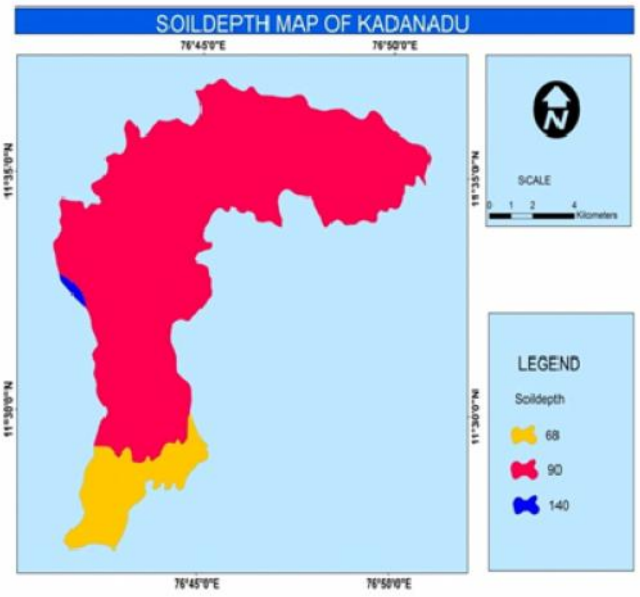


Soil Depth

The soil and soil depth map is collected from the Agriculture Engineering Department of Tamil Nadu and this map was regrouped as Forest Soil (FS), Hilly Forest soil(HF), Karampalayam (KPM), Karampalyam+Nelliyalam (KPM+NYM), Karampalyam+Melithenu (KPM+MTU), Melithenu (MTU), Thalikundha+Vallithotam (TKD + VTM), Nagalli+Nelliyalam. The soil depth feature classified into four classes they are (<68) (MTU), (90) FS, (100) KPM+NYM, (>140) TKD + VTM and ranked according to their contribution of landslide vulnerability zone. Given in table no.3

Table 3. Soil Depth Classes

FID	Soil depth	Weight	Rank	Soilwr	Type
0	68	11	0.3	3.3	Clayey Soil
1	90	11	0.4	4.4	Gravelly Loam Soil
2	140	1	0.3	3.3	Gravelly Clay Soil



Land Use / Land Cover

The land use/land cover map is derived from IRS-1D-LISS III image, with the help of SOI to posheets. The image was classified by visual interpretation and labelled as water bodies, land without scrub, gully erosion land, reserved forest, land with scrub, plantation crop and settlement. These LULC classes are assigned ranks based on the contribution to Landslide vulnerability as shown in Table. Shown in Table no.4

Table 4. Land use / Land cover Classes

FID	OBJECT ID	L U L C Area	Weightage	Rank	WR
0	1	Settlement	14	10	140
2	2	Agriculture	14	20	280
1	3	Forest	14	30	420
3	4	Barran land	14	40	560

Drainage Density

The drainage network of this area digitized using satellite data and SOI toposheets. This drainage network was used for calculation of drainage density. The study area calculates using GIS software. In this study area the classes of drainage density are as shown in table no 5.

Table 5. Drainage Density Classes

FID	OBJECTID	Weight	Rank	DWR
0	1	2	3.3	6.6
1	2	2	6.7	13.4
2	3	2	0.3	0.6
3	4	2	0.5	1

Slope and Slope Aspect

Contour is used to generate DEM for the study area. (30m) can be used to derive information on elevation, slope and slope aspect using the TIN module of ArcGIS 3D Analyst. Slope angle is one of the key factors in inducing slope instability. A slope map with a 100m grid cell size was generated from the DEM. The map represents the spatial distribution of slope values in the area. These were classified into five classes as per the table no 6. The maximum area was occupied by the 0° to 10°, while steep slopes greater than 40° are much less frequent in the area. A slope aspect map with a 40m grid cell size was also generated from the DEM. According to the rain shadow region, weights are assigned. The entire wind ward region has higher landslide susceptibility due to more amount of rainfall.

Table 6. Slope Classes

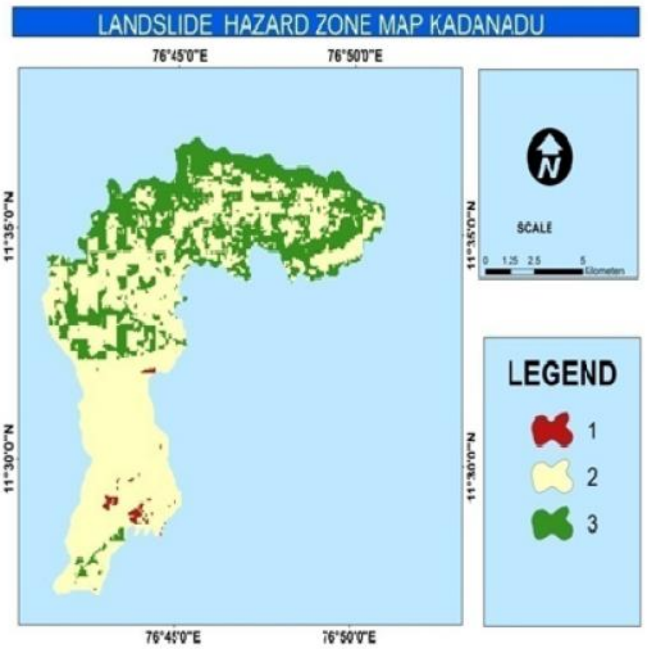
FID	Shape *	GRIDCODE	Rank	Weight	WR
0	Polygon	1	15	25	2.5
1	Polygon	2	2	25	3.75
2	Polygon	3	35	25	3.75
3	Polygon	4	25	25	6.25
4	Polygon	5	25	25	7.5

Landslide Vulnerability Zoning Map

The preparation of landslide vulnerability zoning (LVZ) map is a major step forward in hazard management. In this study, thematic maps are prepared by GIS based qualitative and quantitative techniques which useful to analyse the relationship between landslides and their influencing parameters. Remote sensing and GIS based methodology for LVZ maps are also presented in this study. The weight and rating system based on the relative importance of various causative factors as derived from remotely sensed data and other thematic maps was carried out using various sources. A direct mapping approach will be used to establish the five different LVZ using classical overlay operations after having established maps representing major landslide influencing factors (Saha *et al.*, 2002). The factors being used geomorphology, lineament density, drainage density, slope, geology, soil depth, and land use/land cover. The different classes of thematic layers are assigned the corresponding weights and rating value as attribute information in the GIS and an "attribute map" is generated for each data layer. Summations of these attribute maps are then multiplied by the corresponding weights and rating to yield the landslide susceptibility index (LVI) for each grid cell. The basic pre-requisite for landslide vulnerability zonation studies is the determination of weight and rating values representing the relative importance of factors and their categories respectively for landslide occurrence. In this study, these weights and ratings are determined based on subject knowledge, and the weights and rating for each parameters were multiplied by the relevant parameter maps and then, all the weights and rating parameter maps were overlaid. In this way, a map having continuous scale of numerical values was obtained. The weight and rating were assigned to each attribute layer and their respective classes. A summation of these layers was carried out and the cumulative score was regrouped into five classes. A judicious way for this classification is to use the relative natural breaks algorithm to separate the landslide vulnerability index into landslide susceptibility classes. In this study, five landslide vulnerability classes were identified (pie diagram) which are very high vulnerability (zone-V), high vulnerability (zone-IV), moderate vulnerability (zone-III), low vulnerability (zone-II) and very low vulnerability (zone-I) zones.

Table 7. Landslide Vulnerability Index

S.No.	Landslide vulnerability Zone	Area
1	Low	72.387235
2	Mediam	45.664797
3	High	0.821457



Landslide Vulnerability Index

For landslide vulnerability analysis using the weights and rankings (Table no- 7) the Landslide Vulnerability Index (LVI) values were computed by summation of each factor's rating multiplied by the weight of each of the factors by using the following as Eq.1. *n*

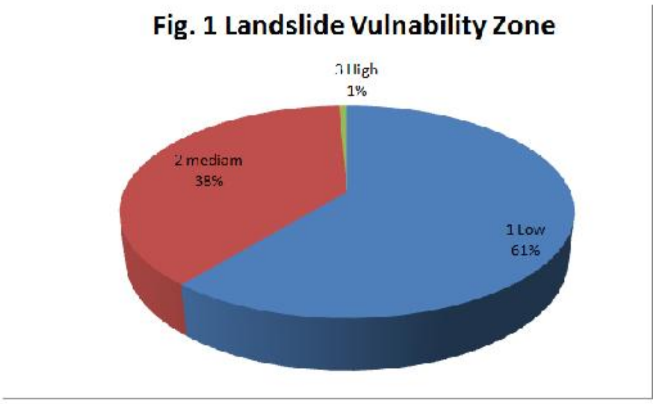
LSI =Σ (*W*i×*R*i) ………………………....….... 100
i =*i*

Where LVI = Landslide Vulnerability Index, Ri = Ratings for the categories of the layers

Wi = Weights for the layers

Table 8. Landslide vulnerability Index Weightage and Ranking

Thematic layer	Map Weight	Individual features	Rank
Geomorphology	6	Least Dissected Plateau	0.2
		Highly Dissected Deflection slope	0.4
		Less Dissected Undulating Plateau	0.1
		Moderately Dissected Plateau	0.3
Geology	7	Chamockite	0.3
		Fissile hornblende boitite gneiss	0.2
		Magnetite quartzite	0.3
		Ultramafic complex	0.2
Drainage Density	2	1	3.3
		2	6.7
		3	0.3
		4	0.5
Slope	25	1	15
		2	2
		3	35
		4	25
		5	25
Soil Depth	11	< 68	0.3
		90	0.4
		> 140	0.3
Landuse	14	Settlement	0.1
		Agriculture	0.2
		Forest	0.3
		Barran area	0.4



Conclusion

Landslide must have occurred in Nilgiri ranges since time immemorial but they have been recorded particularly during expeditions only from the beginning of the last three centuries. The slide occurred in the Sis Para ghat road in 1824, slide occurred in Kadanadu to Mettupalayam road in 1881, landslide occurred in Kadanadu in 1891, 1902, landslide that occurred in Ooty in 1978, landslide that occurred in Coonoor in 1979, landslide that occurred in Coonoor to Mettupalayam highway in 1993, 1998,2001 are major slides occurred in Nilgiris district. The present work is an attempt towards application of GIS for landslide vulnerability mapping. Different thematic layers have been prepared such as geomorphology, drainage density, slope, soil depth, and land use. The numerical weights of the categories of the factors have been determined using subject knowledge. Rank and weights are assigned for each theme. Three landslide susceptible zones were arrived based on landslide susceptibility and was highest in the slope range 45 degree in the study area, the high and very highly susceptible areas are characterized by non- forested areas indicating the influence of vegetation on the initiation of slope instability. The weighted and ranked themes were overlayed in GIS. The cumulative map is classified based its Mean, Standard deviation, Sum. The study area was classified into three vulnerable zones. They are zone I, zone II and zone III. whereas zone I is very low vulnerable while zone III is very high vulnerable zone. In this present study 1% of area falls under zone III, 38 % of area falls under zone II, 61 % of area falls under zone I. When we compare pre-occurred landslide locations over Landslide vulnerability zone map, we found that most of the landslide locations fall under zone I.

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Web Resources

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