Landslide Hazard Zonation of Sirumalai Hills using Remote Sensing and GIS

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Abstract- Landslides are among the major natural disasters or calamities in the world. In hilly terrains of India, including Himalayan mountains landslides have been a major and widely spread natural disasters that strike life and property almost perennially and occupy a position of major concern. The present study Micro level Landslide Hazard Zonation in Sirumalai Area of Dindigul District, Tamilnadu involves in generating complete spatial and non-spatial data collected from different sources .How ever the taluk level maps will act as a basic spatial data contributing many micro level features .The other sources are remote sensing data which will undergo digital image processing to build a themes on land use ,slope, geology ,lineament ,drainage etc. and these items will be vectorized to send it to GIS environment .GPS also act as a data source to some aspects which are not available. The Objectives of the study is to develop the spatial database for landslide analysis, generate the landslide inventory in the entire study area , Lineate the landslide hazard zonation map with Classes-Very high ,high ,moderate &low-classes using Remote sensing and GIS and then to provide the decision support tool for hazard managers and planners. Finally, in GIS the weightage will be allocated to each parameter by considering their contributions to the landslides and overlay analysis will be carried out. On executing this, the final result will help in prioritizing area prone for landslides with triggering parameter .The database will act as base data for future monitoring of landslide occurrences. This study will help in Detailed site-specific database on all parameters which cause land slides, Existing surface feature must be mapped for hazard assessment accuracy using Remote Sensing, GPS and the developmental plan can take place for example, establishment of new roads, electrical pillars etc. The Entire Database will be brought under GIS environment.

Index Terms- Land Slides, Hazard zonation, GI Technology

I. Introduction

Slope failure processes are the common sites in the hilly terrain. These are one major natural hazard which not only results in the loss of life and property but also can economic burden on the society. Hence, there is a necessity for better methods of landslide evaluation and its zonation. A natural hazard means the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon. Though hazard is a process and it is very difficult to map a process which has not yet occurred. However, hazard mapping may be defined as "the identification of those sites where there is a likelihood of hazardous events rather than hazard affected sites". Hazard mapping is stated to be undertaken with respect to 4 key properties, magnitude, location, frequency and time. Under the present study the main emphasis is given on the location of landslides.

Landslide Hazard Zonation may be defined as a technique of classifying an area into zones of relative degrees of potential hazards by ranking of various causative factors operative in a given area, based on their influence in initiation of landslides. It is therefore, the first task to identify various terrain factors which govern the stability of slope. Under the present study an attempt has been made to prepare a landslide hazard zonation map based on the systemization of data acquired from various geo-environmental thematic maps. From exhaustive literature survey and the field checks,

Following geo-environmental factors such as Land use, Drainage, Lineament, Slope are found which are playing a significant role in causing slope instability problems in the area. This paper is aimed at the landslide hazard zonation of Sirumalai hill, Tamil Nadu.

II. Study Area

Sirumalai is a small hill station 20 Km away from Dindigul (Tamil Nadu) on the Natham Road. This region is an important tourist destination in South India. It has a wonderful cool hill climate with forest brook birds and animals. The youngsters can go for trekking and mountaineering adventures. Sirumalai is mentioned in the ancient ayurvedic texts along with Kolli hills as a valuable region with many rare medicinal plants. In fact the Siddi form of healing is said to have been developed by sages in these very hills a few thousand years back.

- Forests of Sirumalai Hills exhibit a considerable variation in their floristic composition and peculiar physiographic, topographic features in addition to altitude and biotic influence.
- The altitudinal range varies strikingly from the plains at Dindigul to 1380 m on the high peaks in Kaluguparai near Ooradi.
- Scrub forests are seen where the biotic interference is more in the foot hills. The soils are red and derived mainly from sand stones and are badly eroded and compacted by heavy grazing. The vegetation is with low density and the species attain a maximum height of 5-10 m.

The Sirumalai Hills are located in Dindigul District, Tamil Nadu, India running 10^o 07' N - 10^o 18' N longitude and 77^o 55'

E - 78° 12' E longitude. They are an isolated, compact group of hills stretching about 6.5 km south of Madurai City. The hills are rectangular in outline, having 19.3 km of length towards north south and 12.8 km of width east-west, covering an area of 288.4 sq. km. The entire study area is divided in to 98 watersheds. Since the hill has dense vegetative cover; drainages are densely concentrated throughout the area. Most of the places, parallel drainage pattern is exists.

Due to this drainage pattern, silting is a common problem. But due to thick vegetative cover, soil erosion is arrested to a greater extent.

The Sirumalai Hills are composed of acid charnockites having characteristic bluish grey color and vary from coarse-grained to fine re-crystallized types. The charnockites carry inclusions of amphibolites and quartzite bands. The quartzite's at north eastern part carry sillimanite, magnetite and seriate. On the northern slopes hornblende biotitic gneisses are found .

The residual laterite soil derived from the charnockites is rich in minerals and supports the diversified vegetation. The surface soil is mixed with pebbles in the deciduous and the savanna belts. The soil is grayish yellow laterite clay in evergreen forest and is loamy blackish in the plantations. The later is rich in humus.

The maximum temperatures occur in the months of May (29.5 °C) and the minimum temperatures occur in the months of January (18.5 °C) respectively.

The annual rainfall is around 1100 mm, with approximately 69 rainy days in two seasons; the maximum rainfall is from the North-East monsoon (October-November). April-June is the hot summer season. The humidity is maximum in the rainy months (90%) and minimum in the summer months (65%).

The water level touched the total height of 21 feet in kodaganar dam. Inflow and discharge were 76,800 cusecs. Varadhamanadhi dam has 70.70 feet, which was above the total height of 66.47 feet. Inflow and discharge were 6,823 cusecs.

The forests of this hill may be broadly classified under the following types according to the revised survey of the forest types of India by Champion and Seth (1968).

a. Lateritic semi-evergreen forest
b. Southern moist mixed deciduous forest
c. Southern dry mixed deciduous forest
d. Secondary deciduous forest
e. Southern thorn forest
f. Southern Euphorbia Scrub
g. Riparian fringing Forest
h. Tropical dry evergreen forest

This forest is in the eastern and north eastern foot hill of Sirumalai.

III. OBJECTIVES

The objectives of the study area:

1. To develop a spatial database for landslide analysis.
2. To generate a landslide inventory in the entire study area.
3. To delineate a Landslide Hazard Zonation Map with classes - very high, high, moderate and low - classes using remote sensing and GIS.
4. To provide a decision support tool for hazard managers and planners.

IV. DATA SOURCES

We have used the data from the following sources

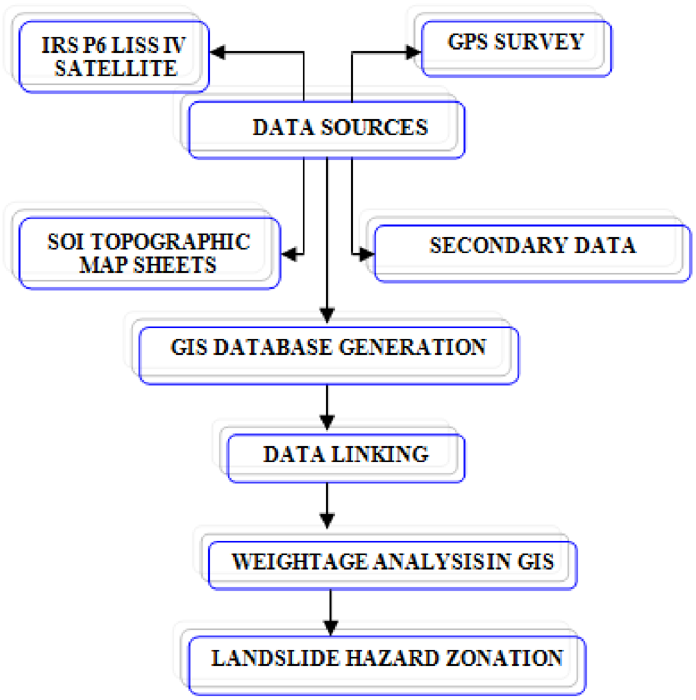
- Satellite Image of IRS – P6 LISS –IV.
- Survey of India topographic map sheets of 58 F/15, F/16, J/3, and J/4.
- Mines Department, Collectorate, Dindigul.
- National Information Centre, Public Works Department, Chennai.

V. METHODOLOGY

The present study involves in generating complete spatial and non-spatial data collected from different sources. However village level maps will act as a basic spatial data contributing many micro level features. Other sources are Remote Sensing data which will undergo digital image processing to build themes on land use, slope, geology, lineament, drainage etc and these items will be vectorised to send it to GIS environment. GPS will also act as data source to some aspects which are not available.

Finally, in GIS, weight age will be allocated to each parameter by considering their contributions to the landslides and overlay analysis will be carried out. On executing this, the final result will help in prioritizing area prone for landslides with triggering parameter. This database will act as base data for future monitoring of landslide occurrences. The flowchart of the methodology is given in Flow chart No.1.

Flow Chart No.1



5.1 LAND USE

Land use refers to "man's activities on land, which are directly related to the land". Land cover denotes "the vegetation and artificial constructions covering the land surface".

Assessment of use and misuse of land is the prerequisite to plan the utilization of resources. Land utilization survey mapping is the obvious requirement to make such estimates. Information on the rate and kind of change in the use of land resources is essential for proper planning, management and regularizing the use of these resources. To overcome the problems associated with food and environment, Planners must have the knowledge about the existing land use and the trends of change over time.

Land use is a key concept in the town planning profession. A major objective of planning exercise is to determine how much space and what kind of facilities a community will need for activities, in order to perform its functions. An inventory of land uses will show the type and amount of space used by the urban activities system. Land use map was prepared using IRS P6 LISS-IV declassified into ten classes and the areal extent of each class the land use map of the study area is shown in the table 1.

Different types of forests are the major land use categories in Sirumalai area. Deciduous open forest is found mostly in fringe areas. Coffee plantation is commonly occurring as patches in fairly sloppy areas. Semi ever green forest, both dense and open category, is found in relatively small areas / patches.

The main land use in the study area is shown in the fig. 1. Deciduous (Fairly Dense Forest) (both wet land and dry land), which occupies around 99.95 sq. km., constituting 34.5 % of the total area. Another 15.1% of the area is occupied by Scrub forest, which is nearly 43.11 sq. km. Deciduous (Dense Forest) occupied 40.39 sq. km., constituting 14.1% of the total study area followed by Deciduous (Open Forest) occupied by 37.67 sq. km and 13.1 %. Degraded Forest and Plantation area is equally covered area of 27.5 sq. km., and contributing 9.5 % of the total study area. The remaining classes namely Fallow land, Land with Scrub, Semi Ever Green (Dense Forest) and Semi Evergreen (Open Forest) together occupy 12.3 sq. km and represent 4.2 % of the total area.

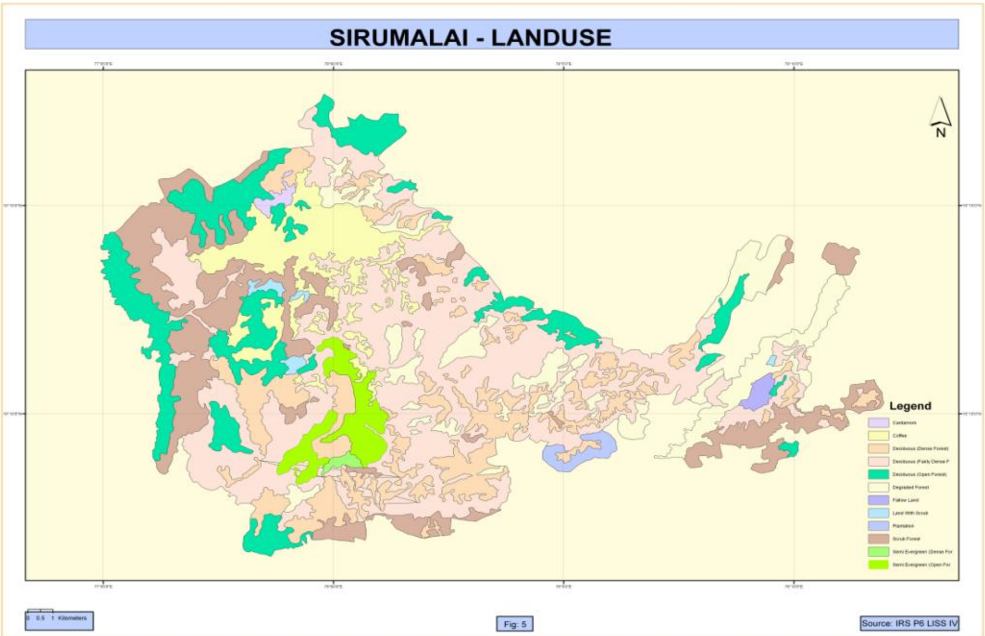


Table 1
Land use

S.No	LAND USE CLASS			Class
1	Deciduous (Dense Forest)	40.4	14.1	Low
2	Deciduous (Fairly Dense Forest)	99.9	34.5	Low
3	Deciduous (Open Forest)	37.7	13.1	High
4	Degraded Forest	27.5	9.5	High
5	Fallow Land	1.2	0.4	Medium
6	Land with Scrub	1.5	0.5	Medium
7	Plantation	27.5	9.5	Medium
8	Scrub Forest	43.1	15.1	High
9	Semi Evergreen (Dense Forest)	0.7	0.2	High

10	Semi Evergreen (Open Forest)	8.9	3.1	High

Drainage

Drainage density appears to be the most important, promising and useful variable in morph metric analysis of drainage networks, as it is related to the dynamic nature of the stream segments and the area. Values of drainage density depict the stages of geomorphic development of concerned area. Lower values indicate old stage and higher values indicate early mature to youth stage of geomorphic development. Generally, low drainage density is found in regions of highly resistant or highly permeable subsoil materials, under dense vegetation cover and low relief. And high drainage density is favored in regions of weak or impermeable surface materials, sparse vegetation and mountain relief.

The idea of drainage density was introduced by Horton (1945,) subsequently followed by Gardiner (1971), Gregory and Gardiner (1975) and others. The drainage density may be defined as the ration between the total channels lengths cumulated for all orders within a basin to the basin area. It is obtained with the help of following formula:

Drainage Density (Dd) = Stream Length / Basin Area

The drainage map in 1:50000 scales were prepared by using Survey of India topographic map sheet. For preparing the drainage density map, 1 cm x 1 cm grid was prepared (which is equivalent to 0.5 sq. km. on the ground) and the drainage map (Fig. 2) is superimposed over the grid to measure the length of drainage in each grid and the drainage density is shown in the table 2.

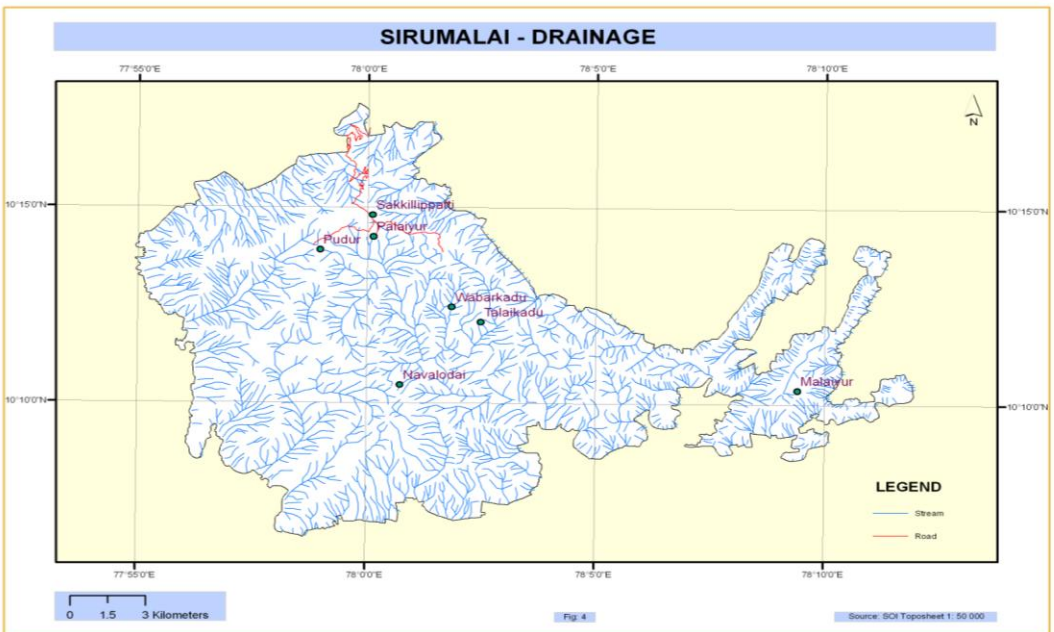


TABLE 2
Drainage Density

S. No	**Drainage Density (Km. & sq.km)**	Area in sq.Km	**Area in %**	**Class**
1	< 0.5	35.1	12.2	High
2	0.5 – 2.5	19.1	6.6	Medium
3	>2.5	234.2	81.2	Low

The characteristic of drainage indicates that increase in drainage density choices are more for landslides and vice versa. Ground water potentiality in the high drainage density area is less due to high draining ability leading to the poor infiltration capacity. Drainage density is high in edges of the study area occupied 35.1 sq. km., and constitutes 12.2 %, most of the lows drainage density is found middle of the study area occupied 19 sq.km and 6.6 % and other areas are covered by medium drainage density covered 234.2 sq. km and 81.2 % of the total study area.

5.3 LINEAMENTS

Lineaments representing the faults, fractures, shear zones, etc., are the most obvious structural interpretations on the satellite imagery. They control the occurrence and movements of ground water in hard rock terrain.

They occur in parallel sets in different directions indicating different episodes of tectonic disturbances. They appear as linear to curvilinear lines on the satellite and are often marked by the presence of moisture, alignment of vegetation, straight streams / river courses, alignment of tanks / ponds, etc. These lineaments can be further sub-divided into faults, fractures, shear zones and thrusts based on the image characters and geological evidences.

Lineaments are special types of patterns used to describe linear features, which are visible as long, narrow, relatively straight tonal alignments in satellite imagery. The lineaments may be a joint, fracture, and dyke system or straight courses of streams. The usefulness of satellite data in identifying linear features is usually the zones of localization of ground water. For the preparation of lineament map in the study area, IRS P6 LISS-IV has been used.

Lineament density map was prepared by measuring the length of lineaments in each one sq. km. grid. From the analysis, it could be identified that the lineament density is low in most of the areas followed by medium density and then by high density. High lineament density is seen as small patches, which are distributed mainly along the foothills of the study area (Fig 3). The lineament density is classified according to the landslide zonation, and it is shown in Table 3.

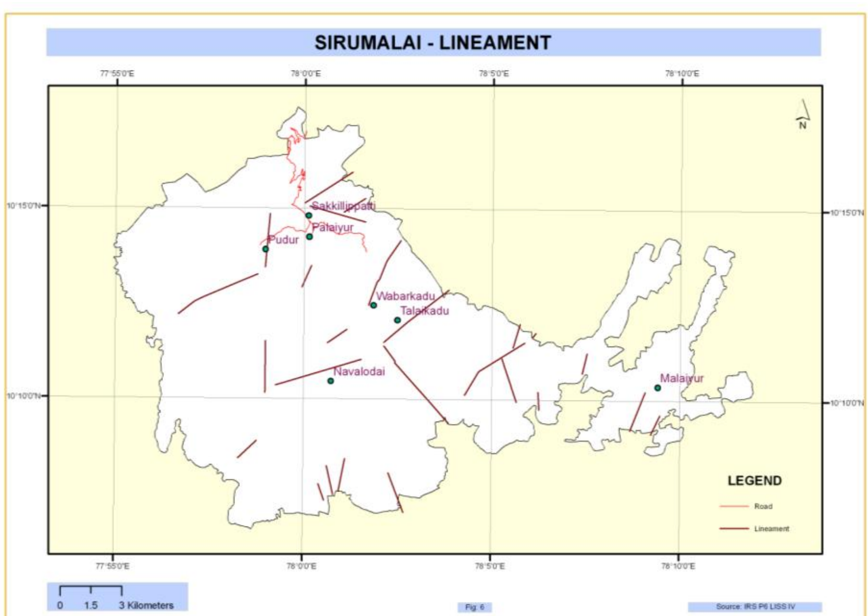


Table .3
Lineament Density

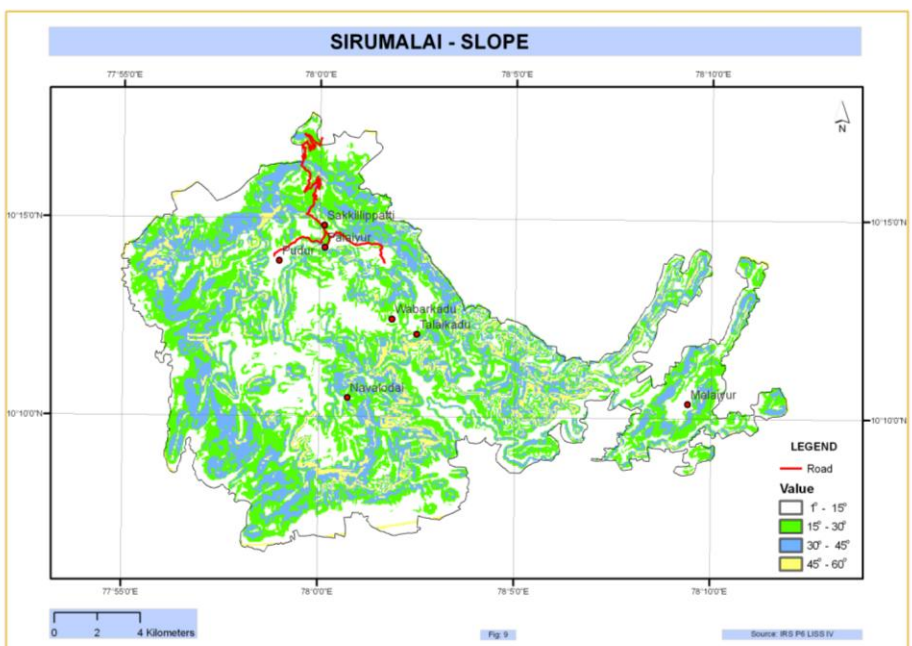
S.No	**Lineament Density (in km/ sq. km.)**	Area in sq. km.	**Class**
1	> 3	3.0	High
2	1.5 - 3	211.7	Medium
3	<1.5	73.7	Low

Using lineament data, the lineament frequency contours were drawn. This was done by counting the total number of lineaments per 0.25 sq. km, plotting them in the respective grid centres and contouring them. Over such lineament frequency contours varied from 1to 6 in the area. The number of landslides falling in >3, 1.5 – 3, and <1.5 lineament frequency classes and landslide incidence. The table has shown that the maximum number of landslides have fallen in between 1.5 – 3 lineament.

CONTOUR & SLOPE

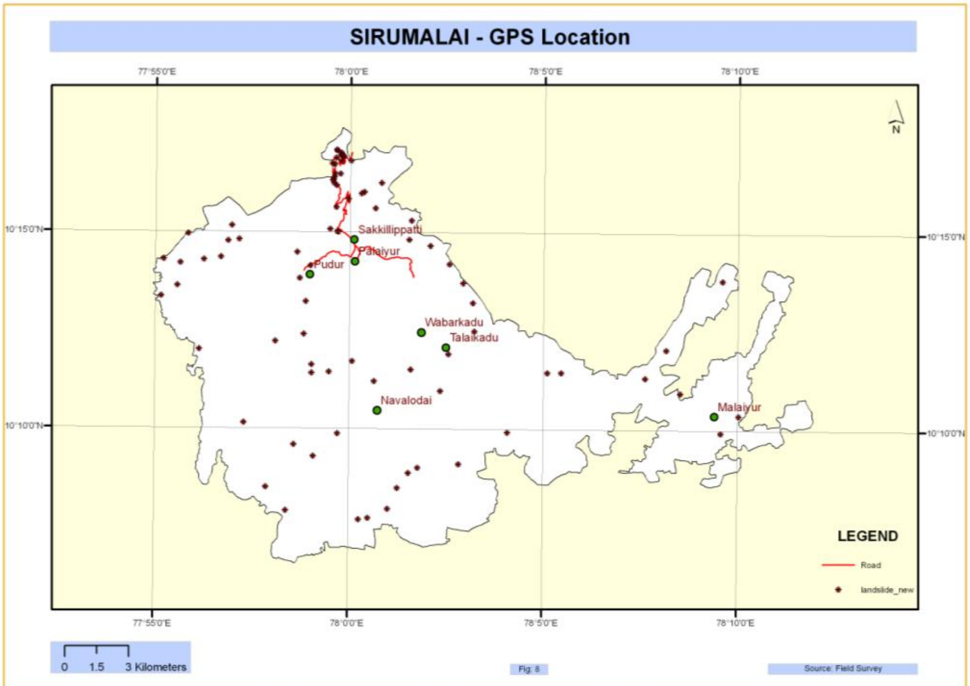
Slope is a very important parameter in any landslide hazard zonation mapping. Different slope categories are derived based on 1: 50,000 scale topographic maps at 20 meter contour interval. With the help of spot height map, the slope map has been prepared and it is shown in the figure 4. If the slope is higher then there is a chance of occurrence of landslide. In the study area the slope varies from 0° to 60°. The entire slope map is divided into four categories as follows: 45° - 60° - "very steeply sloping", 30°-45° - "steeply sloping", 15°-30° - "moderatel y sloping" and 0°-15° - "gently sloping".

Most of the study area occupies Moderately Steep to Steep Slope and Very Steep Slope category.



VI. GLOBAL POSITIONING SYSTEM (GPS)

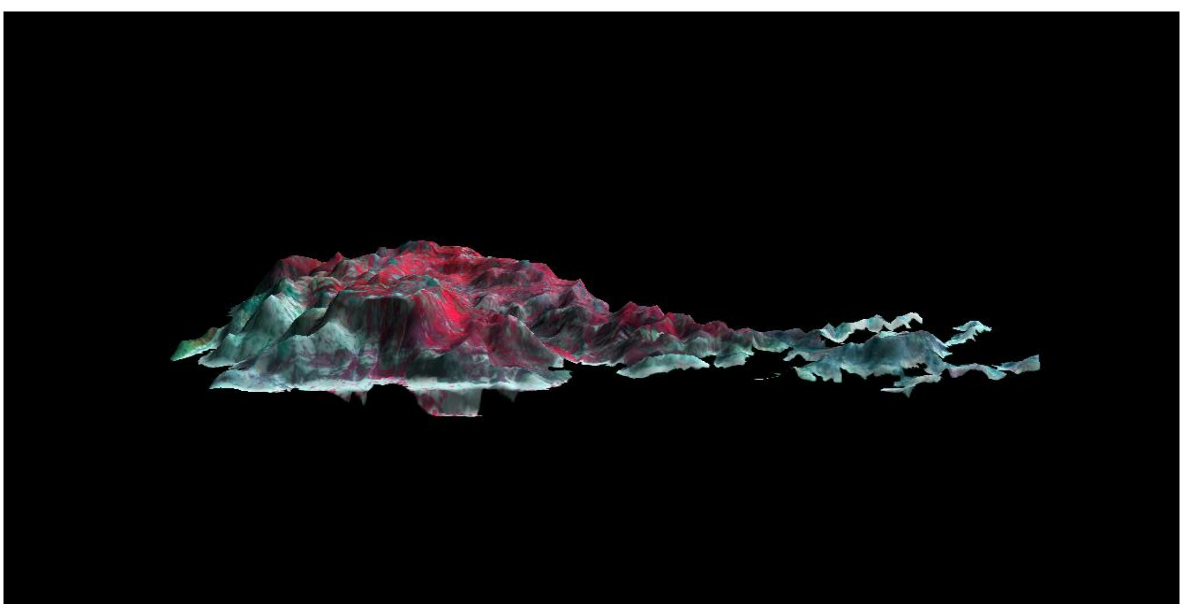
GPS is a useful tool for detecting the locations of first stage disaster. It can detect land movement and aid in determining the boundary of the landslide area. Monitors can be placed anywhere one can access, and the monitors are relatively easy to operate. There are some significant disadvantages involved in using GPS, however. Several of these disadvantages are precision which is affected by the number of observable satellites present, the obstruction of the observation point, and the monitoring of installed GPS receivers which have been placed out in the field. By using GPS the locations of land slides occurred zones are shown in the figure 5.



VII. DIGITAL ELEVATION MODEL

The term digital elevation model or DEM is frequently used to refer to any digital representation of the topographic surface. However, most often it is used to refer specifically to a raster or regular grid of spot heights. The map for the digital elevation model is prepared from the contour map and it is shown in the figure 6. Using the ERDAS imagine, Digital Elevation Model is created.

Fig.6



VIII. LANDSLIDE HAZARD ZONATION

The term landslide comprises almost all varieties of mass movements on slopes, including some, such as rock-falls, topples and debris flows, that involve little or no true sliding.

In this report the term "zonation" applies in a general sense to division of the land surface into areas and the ranking of these areas according to degrees of actual or potential hazard from landslides or other mass movements on slopes. It does not necessarily imply legal restriction or regulation by zoning ordinances or laws.

Many hundreds of maps of landslides or of their deposits, old or new and active, have been made throughout the world, and to a certain degree they often indicate areas susceptible to future problems. But emphasis is placed here on the far fewer number of studies that go farther and attempt to assign degrees of hazard to mapped areas.

GIS software was used for integrating different thematic maps and assigning their combined effect. These thematic maps were quantified by giving them a relative score. In this process the different thematic maps which were carrying out the rasterization. The cross match of each parameter was carried out with the existing landslide map.and finally the score for each class of the theme was calculated using the formula.

Z = Xn/Xy X/Y
Where, Z Score of the class
Xn Area occupied by landslides in a particular class
Yn Area occupied by that class
X Total are of the landslides
Y = Total area

IX. RESULT

Integration of grid cells overlay is utilized for the present study (deGraff and Ronesburg, 1980). Here all the controlling parameters are combined by giving equal weightages for all the themes and the final map is reclassified into threee zones. i.e. low, medium and high hazardous zones.

When the weighted % is taken into consideration using the formula,
Weighted % = Landslide area / Total Area
-------------------------------- x 100
S (Landslide area particular class / Total area of the particular class)

It is found that high and very high hazardous zones are covering approximately 27%, the moderate is covering 70% and the low hazardous zones are covering <3% of the area. The approach of landslide hazard zonation should have more significant to the classification of the area in the term of vulnerability to landslide hazard rather than merely mapping. The study has brought out the use of GIS and Remote Sensing techniques as a tool for the prognosis of landslide.

By integrating the all the four parameters Land use, Drainage, Lineament and Slope the Landslide Hazard Zonation map has been divided in to three zones and it is shown in the fig 7. The areal extent of each class is shown in the Table 4.

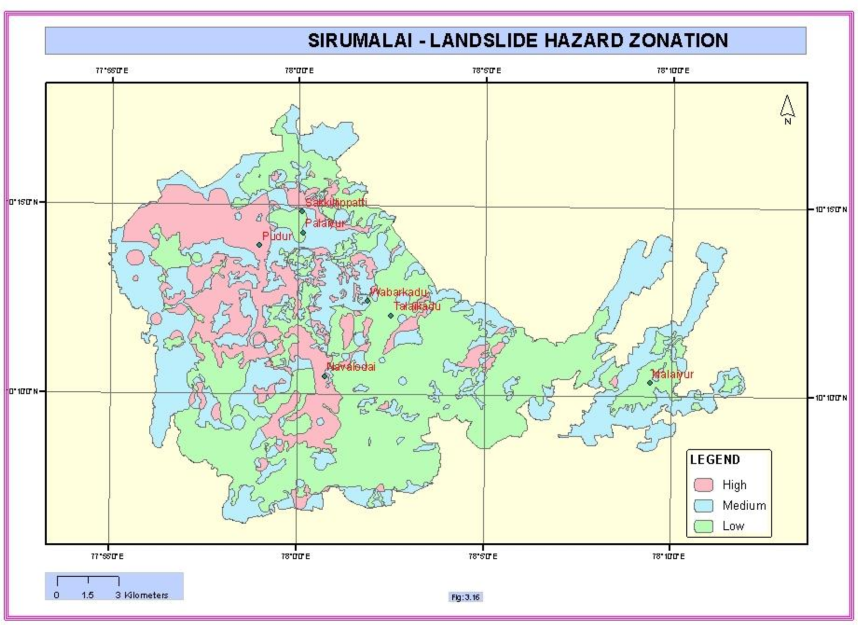


Table 4.

S.No	Landslide Hazardous Zonation Class	Area (in Sq.km)
1	High	128.45
2	Medium	103.23
3	Low	56.64

The central and western part of the study area is occupied by the high landslide zonation class and covered by 56.64 sq. km., the medium class is occupied by eastern and spread over the western part of the study area and covered by 103.23 sq. km.,. The low class area is occupied by north, south and some parts of eastern side and covered by 128.45 sq. km.,.

X. CONCLUSION

Based on the hazard zonation and risk assessment prediction, some of the area needs much more careful consideration taken of their especially the areas where lives and properties are involve very high risk areas cover 56.64 sq. km; the most important of them are listed below:

i. Sloping areas at the road slope.
ii. Some areas, especially the area located at the edge of urban area unit which is normally either bounded by hill slope or where building is done on the constructed earth fill slope.
iii. Some areas of slope along the main road which are parallel to the Stream network.

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