

# Geo-Spatial Analysis of Landslide Vulnerability Mapping in The Nilgiris District, Tamil Nadu, India

<sup>1</sup>J. Murugesan & <sup>2</sup>P. H. Anand

<sup>1</sup>Associate Professor and Head, PG & Research Department of Geography, Periyar EVR College (Autonomous), Tiruchirappalli, Tamil Nadu (India)

<sup>2</sup>Former Associate Professor, Head and PG & Research Department of Geography, Government Arts College (Autonomous), Kumbakonam, Tamil Nadu (India)

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### Corresponding Author

Email: param06[at]rediffmail.com

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## ABSTRACT

Landslide is an important natural hazard during monsoon season in The Nilgiris Mountains of South India. This paper has appraised the Vulnerability of Landslide for The Nilgiris District, Tamil Nadu by using Geographic Information System (GIS) and Remotely Sensed data. There are different methods has been adopted for Landslide Vulnerability Zonation Mapping (LVM) resulting into differing types of outputs. In this paper a new method was attempted for The Nilgiris District, Tamil Nadu by assigning weightages to five Geosystem parameters viz: Lithology, Lineament Density, Geomorphology, Slope and Land use / Land cover and their sub-classes on the basis of their responses to landslides and integrated such weighted five Zones to arrive finally at a Landslide Vulnerability Map.

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## 1. Introduction

Landslide is an important Natural hazard and frequently occurring disasters in the hilly regions around the world and affecting human life with their property. Landslides have wide-ranging impact on the people of the affected area in terms of the devastation caused to material and human resources. Landslides in the United States alone cause \$1 to \$2 billion in property damage and over 25 fatalities per year. Posing threats to settlements and structures, landslides often result in catastrophic damage to highways, railways, waterways, and pipelines. According to the U.S. Transportation Research Board, annual costs for the repair of minor slope failures by state departments of transportation exceed \$100 million.

The Nilgiris derives its name from the words 'neel' (blue) and 'giri' (mountain). It is also unknown whether this name comes from the blue smoky haze given off by the eucalyptus trees that cover the area, or because of the Kurunji flower, which blooms every twelve years giving the slopes a bluish tinge (District Census Handbook, 2011). It is situated in Tamil Nadu and is home to the splendid Blue Mountains that are a part of a larger mountain chain known as the Western Ghats, sweeping across the states of Tamil Nadu and Kerala. The elevation of this mountain range varies between 2,280 to 2,290 meters, with the highest peak being Doddabetta at 2,623 meters. The Nilgiris have tea cultivation at the height of 1,000 to above 2,500 meters. This also produces eucalyptus oil and temperate zone vegetables. The Nilgiris have a cool and wet climate and it is a popular summer retreat, with hordes of tourists from across the country flocking the heights in all excitement. There are numerous places where one can engage in trekking. The Nilgiris was once abided of the tribal population. A few tribal groups have been living in the mountain regions of the district. Todas, Kotas, Kurumbas, Irulas and Badagas are the original tribal inhabitants of the

district and they have depended mostly on the natural resources.

Many researches on landslide hazard zonation have been done over the past three decades as the effect of a critical demand for slope instability hazard mapping (Gupta et al. 1993; Anbalagan 1996; Nagarajan et al. 1998; Arora et al. 2004; Sarkar and Gupta 2005; Naithani 2007; Saranathan et al 2010; Kannan et al 2011a). A general idea of the various slope instability hazard zonation methods can be found in Hansen (1984), Hartlen and Viberg (1988), and Guzzetti et al (1999). Landslide susceptibility mapping of areas can be assessed and predicted through scientific investigation of landslides, and thus landslide damage can be reduced through suitable mitigation measures.

The study of vulnerability related to natural disasters has been the focus of different investigations and hence, of several definitions. Westgate and O'Keefe (1976) defined vulnerability as the degree to which a community is at risk from the occurrence of extreme physical or natural phenomena, where risk refers to the probability of occurrence and the degree to which socio-economic and socio-political factors affect the community's capacity to absorb and recover from extreme phenomena. For Varley (1991), vulnerability is a function of the degree of social and self-protection available to potential victims. It is clearly related to the ability of households or communities to cope with and recover from outside events and particularly to shocks and sudden changes (Maskey, 1993). It also concerns the predisposition of a society to experience substantial damage as a result of natural hazards (Clarke and Munasinghe, 1995).

The study is to assess the human influence on the modifications as well as the natures' impact on hill environment. Increasing pressure on land for agriculture and

monoculture plantations displaced an alarmingly high proportion of natural forests and grasslands leading to an extensive loss of biodiversity and turning the Nilgiris into a biodiversity "hotspot". In this hierarchy, the Landslide vulnerability mapping is the starting point and hence a newer GIS based geosystem response modeling was attempted to prepare Landslide Vulnerability Map (LVM) for a part of Nilgiri Mountains of South India.

## 2. The study area

The Nilgiri hills, is one of the smallest districts of Tamilnadu. Etymologically the word Nilgiri means Blue Mountains. The Nilgiris is situated in the Northwestern part of Tamil Nadu bordering Kerala and Karnataka State. The Malabar regions of Kerala bound it on the West, Karnataka on

the North and Coimbatore district on the East and South. The district is spread out between 11° and 11° 55' North Latitudes and 76° 13' and 77° 02' East Longitude. The total area of the district is 2565 sq kms (Fig.1). The Nilgiris district stands 27th place in terms of area among the districts in Tamil Nadu. The district has been divided into two distinct natural divisions- the Nilgiris plateau and the South East Wayanad land. The plateau is marked with hills and very few valleys. The plateau is further sub-divided into four divisions: Peranganad in the extreme East, the Merkunad on the West, the Todanad in the North and the Kundahnad in the South East. The land area in the district is lower in elevation than the plateau and has wide expanses of undulating forests interspersed with fields of paddy and broad patches of bamboo thickets, mainly in Gudalur area.

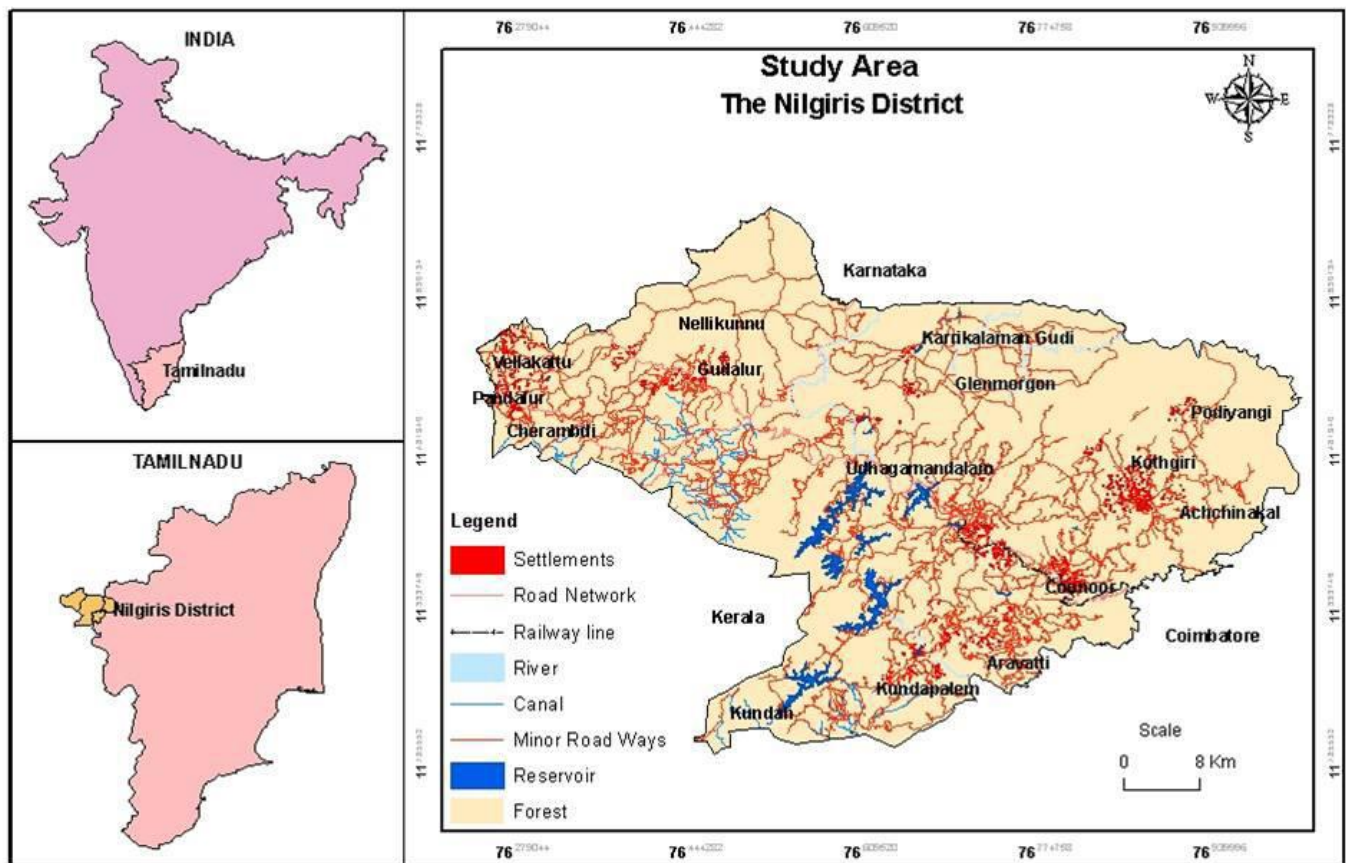


Fig.1

## 3. Materials and Methods

To study the human influence on the hill environment, the topographical information of the district, which covers 58 A/6, 58 A/10 and 58 A/11 have been converted into digital map formats. The control points were taken using GPS for geo-referencing methods. The individual topo sheets were merged to get the overall district physical and cultural landscape. Different shape files were created using ArcCatalogue. To find the changing hill environment in Nilgiris district, Indian Remote Sensing Digital Data for IRS-P6 for the time period 27th February 2010 has been obtained for the Digital Image analysis technique using ENVI 4.0.

The processed image results were converted into raster to vector transformations and different shape files were derived.

The results were downloaded to ArcMap. In the present problem, the road link connecting from foothill (Kallar) to Ooty has been taken and the occurrence of landslides was tracked by using GIS 20 Global Positioning System (GPS). All the landslide occurrences were transferred on to the digital map and re-registered all the points surveyed using GPS. Based on this information, two types of maps like risk and vulnerability were prepared and it has classified from Low to very high zonation pattern.

## 4. Results and Discussion

### 4.1. Landslides Events in The Nilgiris District

In the Indian sub-continent, landslides are common in three major regions namely, the Himalayas in north and northeast, Western Ghats in the southwest and the Nilgiris in

the south. The major factors behind these landslides are active tectonics in the Himalayan landslides, slope erosion and rock fall in the Western Ghats and rainfall in the Nilgiris (Seshagiri et al 1982). A number of studies have been carried out in the Nilgiris by various agencies with different approaches (Seshagiri et al 1982). A case study of debris avalanche at Marappalam in Nilgiris district was reported by Balachandran et al (1996). The Nilgiris district has a long history of disastrous landslide events. Most of the landslides are triggered by heavy intense rainfall in the district and are briefly mention below:

- Worst Storm has occurred around Ooty and Coonoor during 23rd October 1865. Coonoor Railway station was covered with water up to five feet deep. In Ooty Lake rose up to top of willow bound and threatened to breach it.
- In November 1891 heavy rain caused many landslips on the Coonoor Ghat, and did great damage to the Kotagiri - Metuppalayam road.
- Many people were killed in Ooty on account of houses collapses landslides and drowning on 5th November 1978.
- There was continuous heavy rainfall during 12th to 19th November 1979 and there was heavy rain of 102.2 mm at Coonoor and a heavy landslide at Selas in which a house was completely buried in the debris along with 2 women and 3 children.
- There was another 'cloud burst' on 11<sup>th</sup> November 1993 in the upper reach of Marappalam of Coonoor Taluk, about 18 huts situated below the road and washing away Coonoor MTP ghat Road for about 1.50 km. The road traffic was suspended for more than a fortnight. Twelve persons lost their live and 15 persons missing. It is laid that 21 passengers were washed away with two buses. An important highway, sheared stretched of rail road for about 300 meters.
- Two massive landslides were occurred in December 2001 near Pudukadu on the Coonoor-Mettupalayam high way damaging two bridges resulting in the complete closure of traffic. In addition a closer damage was also caused to the railway track between Coonoor and Mettupalayam. Bridge No.55 near hill grove railway station was completely damaged and Bridge No.56 was also damaged.
- Numerous landslides were reported in the early hours on 14 November 2006 killing one and injuring three persons and disrupting traffic in NH-67 and blocking

of mountain rail track between Mettupalayam and Coonoor.

- During 2009, 1150 landslides/landslips were reported in Nilgiris out of these landslides about 98 per cent are minor slips.

#### **4.2. Landslide Vulnerability Mapping (LVM)**

In the entire Nilgiri Mountains, the highly developed area between Coonoor and Ootacamund is facing recurring Landslides and so far more than 350 landslides have been reported. Such landslides were mapped by browsing the earlier work and the interpretation of black and white panchromatic aerial photographs on 1:10,000 scales, by studying them under stereo models using wild APT2 double scanning stereoscope. In such stereo-models, as the actual relief of the terrain is exhibited, the zones of arcuate breaks, escarpments, depressions with concavity along the slopes with the bulged toes in the down slopes, Crescent shaped vegetation banding, Crescent shaped vegetation blanks, Linear and Parallel crevasses indicating the traces of the landslide movements etc were critically mapped and these were field checked. During the process of field checks, few more landslides were also located and all were assembled and the landslide distribution map was prepared. All these lead to the detection and mapping of nearly 350 landslides and palaeoscars in the study area. From amongst these, over 144 landslides and palaeoscars of larger dimension were filtered out and a GIS layer was prepared using Arc-view software showing these landslides.

#### **4.3. Generation of GIS Databases**

Subsequent to the generation of GIS data base on the landslides, GIS data bases were generated individually on five geosystem parameters viz: Lithology, Lineament Density, Geomorphology, Slope and Land use / Land cover, which only generally assign different landslide vulnerability grades to the mountain areas.

#### **4.4. Lithology**

Lithologically, the Nilgiri Mountain is predominantly covered by the Charnockites and these Charnockites have undergone different degrees of weathering. The lithology of the study area was classified into highly weathered, moderately weathered and poorly weathered Charnockites. These zones covered by three classes of Charnockite were digitized by using on screen digitization technique in ArcGIS and lithology map was generated (**Fig.2**).

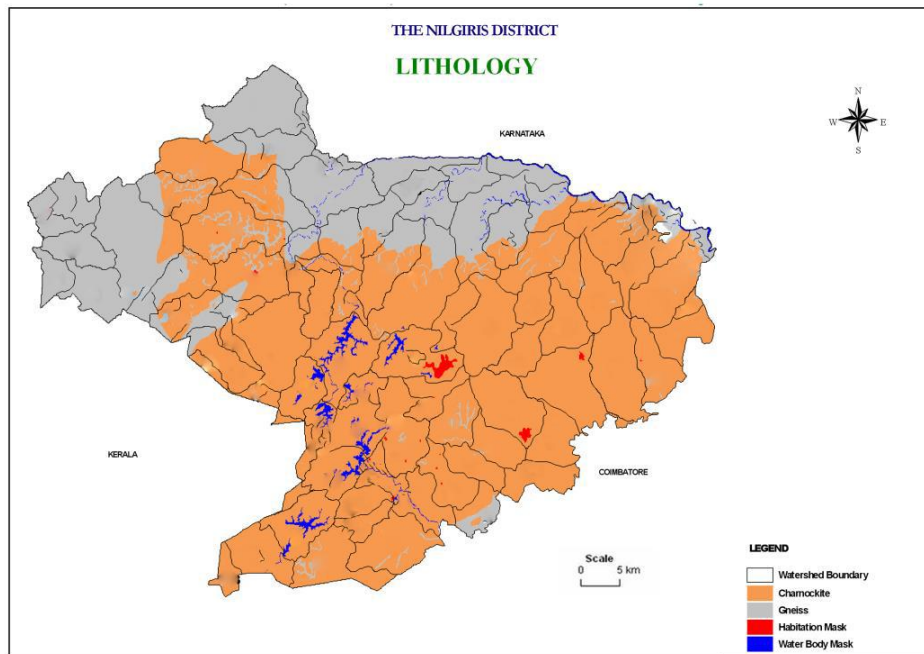


Fig.2.

4.5. Geomorphology

The Charnockite group of rocks with the enclaves of Satyamangalam Schist Complex exposes in the Nilgiri district. It has found in southern part of the district, which is popularly known as "Nilgiri Massif". The Bhavani Group (Peninsular Gneissic complex) comprises fissile hornblende biotite gneiss are occurs in the northern part of the district. The Satyamangalam Schist Complex is represented by quartzsericite / mica schist, ultramafics and banded magnetite quartzite. The Nilgiri Massif is capped by aluminous laterite at a number of places indicating the deep zone of weathering (GSI, 2000). Most of the parts of the district rocks are deeply weathered and the soil thickness is found to be upto 40m with lithomarge is a common feature in the district. The low gradient

of slope is found in Ootacamund, which promotes stagnation of surface water as bogs and swamps (GSI, 2000). The IRS P6 LISS - III data used for mapping the lineaments was subjected to further various image processing techniques, particularly to contrast stretching, false color composites and color composites of principal component images etc. From the same, various geomorphic features were interpreted and these were vectorised as individual polygon classes and GIS data base was generated on geomorphology map (Fig.3). The geomorphic features so interpreted in the study area include crest lines, escarpments, tor cliffs, midslope mounts, conical hills, slopes with natural vegetations, plantations, settlements and barren rocks, barren valleys, filled valleys, barren fracture valleys, filled fracture valleys etc.

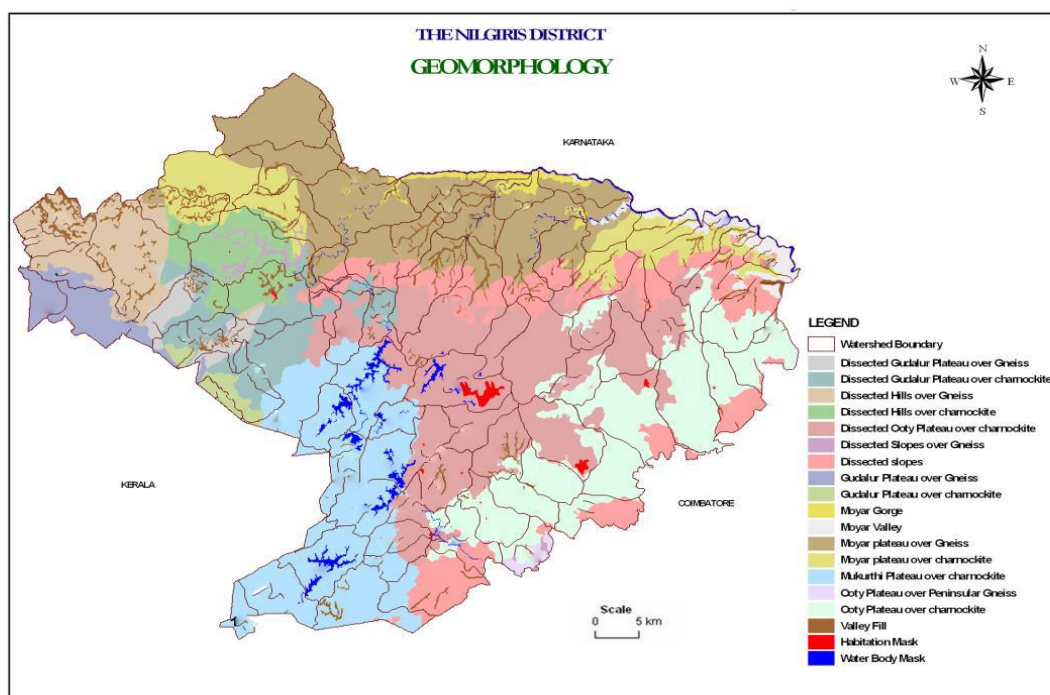


Fig.3.

#### 4.6. Geological Structures

The Nilgiri Hills rise abruptly from the surrounding plains to an elevation of 1370m msl and it is surrounded by the Coimbatore plains in the southeast, Bhavani plains in the northeast, Moyar valley in the north and Gudalur Plateau in the northwest. The prominent hills are Ooty hills, Dodabetta, Kodaibetta, Bhavani Betta and Devabetta. Dodabetta is the highest peak in Tamil Nadu (GSI, 2000). Moyar is a prominent river in the district and flows in an easterly direction along the northern boundary of the district. The drainage is dendritic to radial at places with prominent rapids, cascades and waterfalls.

On the basis of tonal, textural, topographical, drainage and vegetation linearities and curvi-linearities, the fracture controlled lineaments seen in IRS-P6 LISS III Raw and FCC data and DEM wrapped FCC data were mapped and these were field checked for their tectonic origin. From these lineaments, lineament density diagram was prepared by superimposing a grid map having 4687 grids of 250 x 250 m<sup>2</sup> each over the lineament map, measuring the total length of

lineaments per each grid and plotting them in corresponding grid centers. Based on the plotted values, lineament density contours were drawn. The same showed the variance of density values from 0 to 400 mts and this was grouped into 5 classes viz; 0 (Very Low), 0 to 100 (Low), 100 to 200 (Moderate), 200 to 300 (High) and more than 300 (Very High) and GIS database was generated digitizing these five classes of lineament densities as five polygon classes using ARC-GIS again under vector mode (with lines and polygons).

The erosional surfaces such as Dodabetta, Ootacamund, Coonoor and Moyar are recorded in the district. All these erosional surfaces are capped by residual laterite. All Dodabetta surface includes landform such as high peaks, structural hills, and rocky escarpments with or without soil cover around which prominent radial drainage is developed. The Ootacamund and Coonoor surfaces include gentle mounds, with soil cover, stream meanderings and gentle smoothing of the hills. The latter abuts against the former at many places, with break in slope (**Fig.4**).

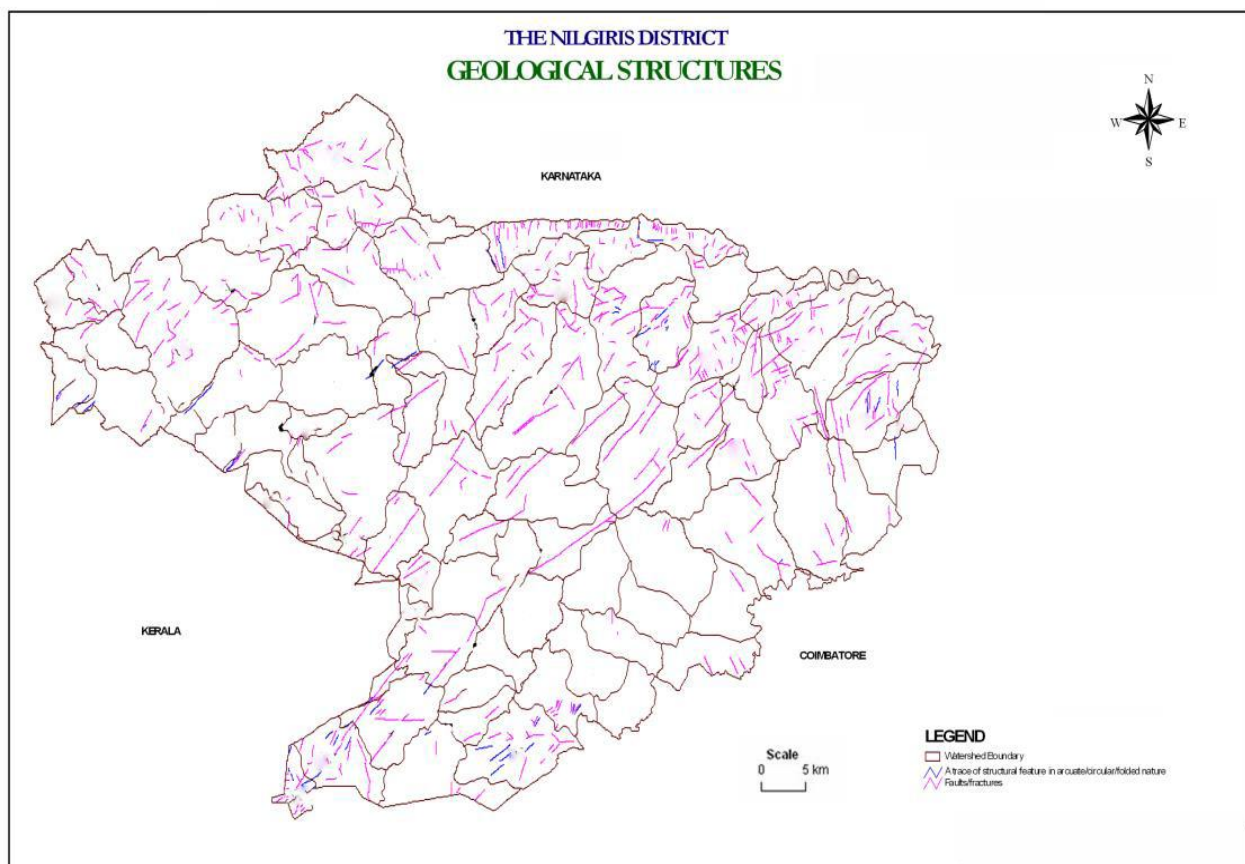


Fig.4.

#### 4.7. Soils

The soils of Nilgiri district can be broadly classified into five major types viz; Lateritic soil, Red sandy soil, Red loam, Black soil, Alluvial and Colluvial soil. Major part of the district is covered by Lateritic soil. The Red sandy soil and Red loams are occurring as small patches. Block soil is developed in the

valleys; where the water logging is also common during the monsoon period. The alluvial and colluvial soils are found along the Valleys and major river courses respectively. **Figure 5** shows that the soils map of Nilgiris district with respect to local place names.

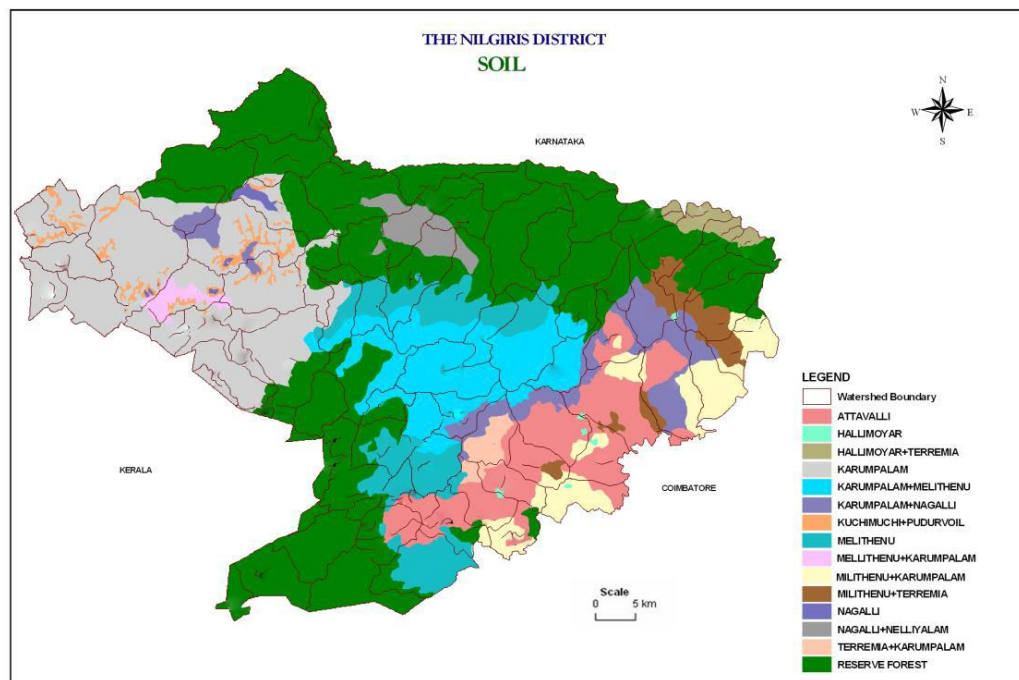


Fig.5.

#### 4.8. Slope

The slopes of the study area were classified into four categories, such as steep (>40 degrees), moderate (40 - 20 degrees), shallow (20 - 3 degrees) and rolling slopes (<3 degrees) by enlarging the topographic sheets of 1: 50,000 scale to 1:12,500 scale. These four classes of slopes were prepared from the topo sheet of 1:12,500 scales by interval measuring the distances between the two contours of 20 meters. For example, if the distance between the two contours was less than 2mm, the said zone was mapped as steep (>40 degrees), 2mm - 4mm as moderate (40-20 degrees), 4mm to 28mm as shallow (20-3 degrees) and more than 28mm as rolling (<3 degrees) slopes. The vector GIS layer was similarly generated for the same showing these four polygon classes of slopes.

#### 4.9. Tectonic Implications

Kilometre scale compound slides of 0.5 to 2 metres slips are observed at Katteri hill site. Both earth material and rocky material were slid from the top of the hills to the bottom. The entire slope was subjected to downwards movements which suggests that the slide might have happened on the hidden blind shear zone preserved beneath the lateritic soil cover. It is possible that the sites of past landslides at Glendale Tea Estate, Elk Hills, Allangy village Slide Yelanathi and also other sites of Nilgiri landslides may represent the locations of palaeo - shear zones.

Tectonically, the Nilgiri granulites are squeezed between E-W dextral Moyar shear zone in the North and NE-SW sinistral Bhavani Shear zone in the Southeast. The area is geodynamically active now along the E-W and NE-SW striking palaeo shear zones originally formed during the Moyar as well as Bhavani Shearing events. The upliftment characters of Western Ghats and reactivations of lineaments were identified

from landscape studies of Vamanapuram basin of Kerala (Sri Kumar Chattopadya et al 2006). It is well known that earthquakes are also a cause of landslides due to propagation of different directional vibrations. There is a noticeable increase in the events of Nilgiri landslides especially after Gujarat republic day earthquake on 26.1.2001. Far-field foreshock of the 2001 Gujarat earthquake released at Nanguneri of Tamil Nadu on January 17, 2001. The micro seismic fracturing events of Southern Granulate Terrain clearly reveal the ongoing transpressive tectonics in Tamil Nadu and Kerala region which has initiated the reactivation of different crystal segments bounded by N-S, NW-SE, NE-SW and E-W running deep shear zones of South India (Manimaran 2007; Manimaran and Renuga, 2007) which in turn resulted in instability of the slopes and increase of landslides events at Nilgiri Hills. Continuous small scale seismotectonic activities are also capable of inducing landslides when other conditions are favourable.

#### 4.10. Land Use / Land Cover

The Land use / Land cover of the study area is yet another important parameter controlling the landslides as it provides varied degrees of protection and vulnerability to landslides. For example the natural vegetation, thick forests anchor, the soils and protect the slopes from slope failures. Whereas, the plantations, settlements, highly developed areas with net work of road increase the probability of Landslides occurrence. By duly interpreting the raw and digitally processed IRS P6 LISS - III data, land use and land cover features were interpreted. The features thus interpreted viz: dense forests, forest blanks, open forests, plantations, reserve forests, scrub forests, settlements, water bodies, water logged areas etc., were created by using ArcGIS and finally land use and land cover map was generated showing all the feature classes (Fig. 6).

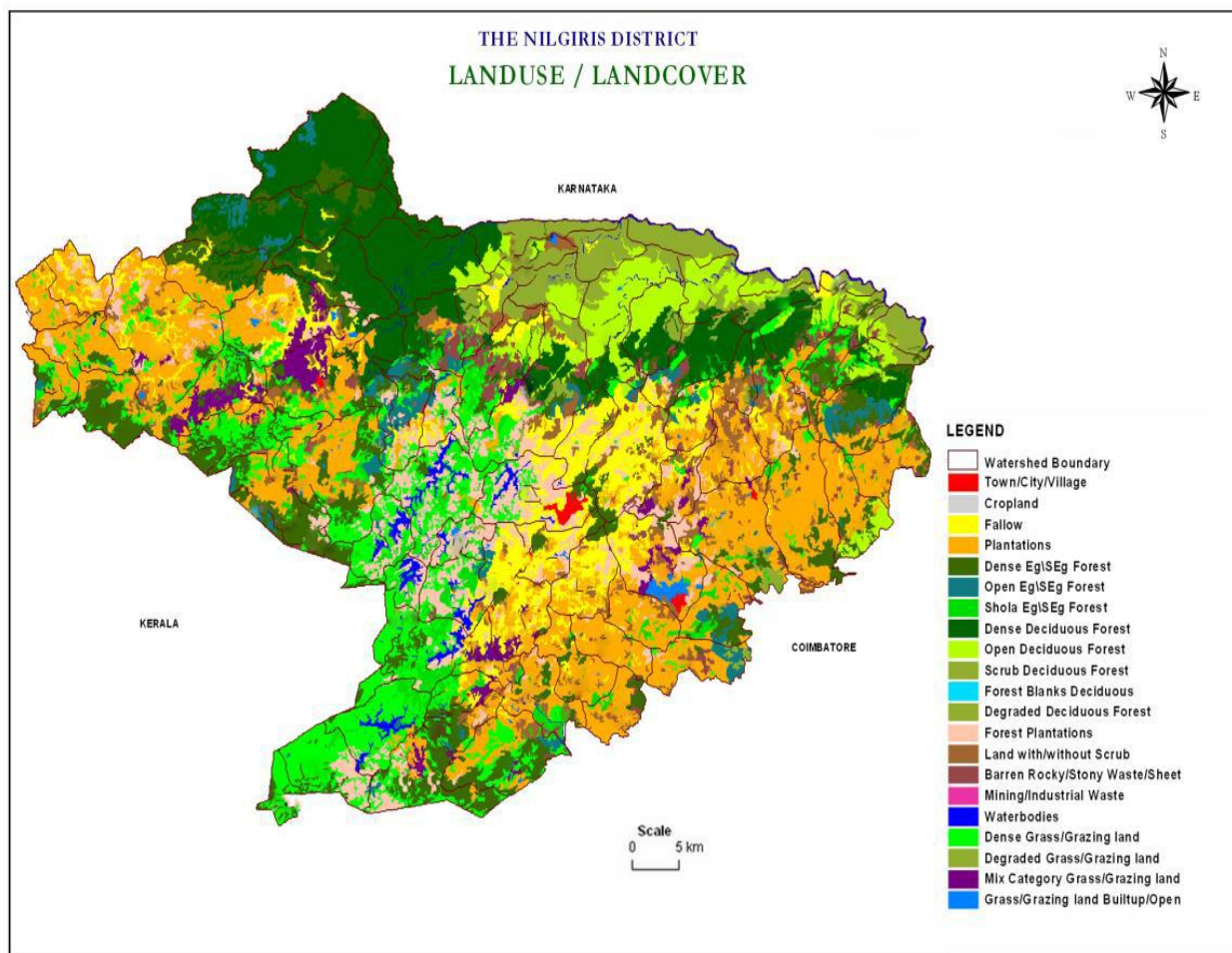


Fig. 6.

#### 4.11. Landslide Vulnerability Assessment

Subsequent to the generation of raster GIS layers on the above five geosystem parameters, the Landslide Vulnerability Weightages were assigned to each feature class of all the five geosystem layers based on the number of landslides per unit area. As these are now raster layers, the polygon classes are referred to as feature classes. The same was done by overlaying the GIS layer on landslides over the above five raster GIS layers of different geosystems individually, counting the total number of landslides falling in individual feature class of these five raster layers, counting the total number of pixel in each feature class and dividing the number of landslides (LS) falling in each feature class by the total number pixels (A) covered by the corresponding feature class. Such ratios so derived were multiplied by 1000 and the Landslide Vulnerability Weightages (LVW) was thus assigned to each feature class. The above derived landslide vulnerability weightages were assigned to each pixel of the each feature class in all the five raster geosystem layers. Such LVW will be same for all the pixels of a particular feature class in the five geosystem layers. For example all the 2, 17,983 pixels of highly weathered Charnockite will have LVW value of 0.46 and are shown in red colour. Subsequent to the assignment of LV Weightages (LVW) to all the feature classes of the five rasterised geosystem layers, these were all integrated together using Raster Calculator of the Spatial Analyst extension menu of ArcGIS. This has added the LVW value of each pixel of the lithology raster layer with the corresponding pixels of the weighted raster layers of the remaining four Geo systems and

the final integrated GIS layer was generated. Such an integrated GIS output had the totally accrued LV Weightages in all their 5, 48,884 pixels which ranged from 0.2 to 6. Then, the pixels which were having 0.2 to 1.36 LVW in the final integrated layer were marked as very low, 1.37 to 2.52 as low, 2.53 to 3.68 as moderate, 3.69 to 4.84 as high and 4.85 to 6 as very high, as far as the landslide vulnerability of the area is concerned.

In the Figure 7 shows the landslide vulnerability was done by superimposing the landslide distribution layer over the final integrated GIS layer on landslide vulnerability. The same has shown final derived weightages, a map on landslide vulnerable zones was prepared showing the below 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. In the present study, Landslide Vulnerability Zonation mapping has been carried out using Landslide per unit area method. As far

as the geosystem parameters are concerned, five vital geosystem parameters were used for such vulnerability

mapping. The validation showed that this method can be successfully employed for landslide vulnerability mapping.

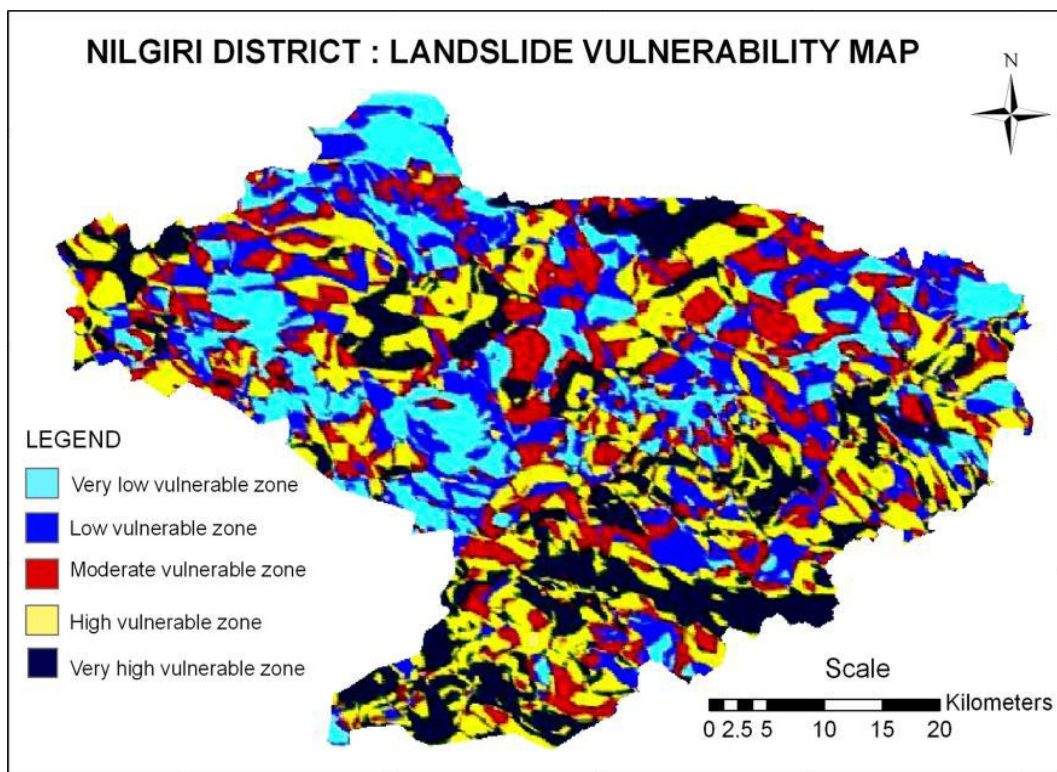


Fig. 7.

## 5. Conclusion

A landslide hazard assessment, which is commonly in the form of a map, provides people with a practical and cost-effective way to recognize areas where landslides exist or could occur. So far landslide hazard zonation mapping for the study area has been attempted for the district only based on Landslide Susceptibility Index (LSI) considering factors like lithology, slope angle, distance from major thrust/faults, and land use pattern and drainage density in relation to frequency of existing landslides. These approaches are qualitative and some of them are quantification. Risk analysis involves assessing the hazard as well as considering the consequences if people and property are affected by these hazards. This paper provided an overview of the risk management processes on landslides.

The district is categorized under severe to very high landslide hazard prone areas. This indicates the area is well known for the danger of landslides, and for the perennial threat to life and property. Investments on landslide remediation

measures, on public education and on early warning systems are strongly indicated. One of the most difficult problems concerning landslide hazards in place like Nilgiris is dealing with existing urban areas where buildings are constructed on or close to a landslide. The ideal approach in this situation is to avoid further development in high risk landslide prone areas, limit existing use rights to rebuild, and limit the use of buildings. Hence, in the present study, Landslide Vulnerability Zonation mapping has been carried out by using Landslide per unit area method. As far as the geosystem parameters are concerned, five vital geosystem parameters were used for such vulnerability mapping. The validation showed that this method could be successfully employed for landslide vulnerability mapping. This study is helping academics, local government and public interest nationally or internationally can benefit from further research in this area.

## References

1. Bhandari R.K. (2006), The Indian Landslide Scenario, Strategic Issues and Action Points, (A Key Note address – Technical Session on Landslides) First India Disaster Management Congress, New Delhi, 2930.
2. Carrara, A., Cardinali, M., Detti, R., Guzzetti, F., Pasqui, V., Reich- enbach, P., (1990). Geographical information systems and multi- variate models in landslide hazard evaluation. In: Cancelli, A. (Ed.), Alps 90. Int. Conf. and Field Workshop on Landslides, Milano, pp. 17 – 28.
3. Clarke, C., Munasinghe, M., (1995). Economic aspects of disasters and sustainable development: an introduction. In: Munasinghe, M., Clarke, C. (Eds.), Disaster Prevention for Sustainable Development, Economy and Policy Issues. IDNDR and the World Bank, Washington, pp. 1–10.
4. Corominas, J., Moya, J., (1996). Historical landslides in the eastern Pyrenees and their relation to rainy events . In: Chaco´n, J., Iri- garay, C., Ferna´ndez, T. (Eds.), Landslides. Balkema, Rotter- dam, pp. 125–132.

5. Geological survey of India, (1982). The Nilgiri Landslides – Miscellaneous publications, No. 57.
6. GSI (2000), District Resource Map Series: Nilgiri District Tamil Nadu, published by Geological Survey of India explanatory Note. <http://nilgiris.nic.in/disaster.htm>
7. Jacob, T.G.: Wayanad: Misery in an Emerald Bowl. Mumbai: VAK, (2006). Keystone Foundation: The Choice of Grain: Adivasis and Food Sovereignty in the Nilgiris. Kotagiri: 2005.
8. Krishnaswamy, V.S (1980). Geological aspects of landslides with particular reference to Himalayan region, Proceedings International Symposium on Landslides in India, Volume 2.
9. Maskey, A., (1993). Vulnerability accumulation in peripheral regions in Latin America: the challenge for disaster prevention and management. In: Merriman, P.A., Browitt, C.W.A. (Eds.), Natural Disasters: Protecting Vulnerable Communities. Thomas Telford, London, pp. 461–472.
10. Murugesan, J. (2013). The Nilgiris District: Modifications of Hill Environment and Implications Using Geo-Spatial Techniques, Unpublished (Ph.D) thesis, Department of Geography, Government Arts College (Auto)-Kumbakonam, Bharathidasan University, Thiruchirappalli.
11. Seshagiri D. N. Badrinarayanan S. Upendran R. Lakshmikantham C.B, and Srinivasan V,(1982). "The Nilgiris landslide," Miscellaneous publication No. 57. Geological Survey of India.
12. Thanavelu C. and Chandrasekaran (2008), "Geotechnical Assessment of November 2006 landslides in the Nilgiris Tamil Nadu," Abstract Volume: Proceedings of the National Seminar on Challenges in Engineering Geology, 03rd to 05th December 2008.
13. The Hindu (2009), Scale of damage in Nilgiris huge, relief works apace, cited on: <http://www.thehindu.com/2009/11/12/stories/2009111258110100.htm>.
14. Varley, A., (1991). Disasters: vulnerability and response. Disasters 15 (3), 285–287.
15. Westgate, K.N., O'Keefe, P., (1976). Some Definitions of Disaster, Disaster Research Unit Occasional Paper No. 4. Department of Geography, University of Bradford.