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# Disaster Management and mapping using Remote Sensing and GIS

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## ABSTRACT

Landslides and Land erosions are one of the important hazards in the hilly region. They cause more losses to the lives and property of that area. The increase in population and settlement has increased the effects of Natural Disasters. Landslides can't be fully prevented but their effects and damages can be minimized, if it is predicated before their occurrences. By identifying the landslides, remote sensing and GIS, help managing the vulnerable disaster. Remotely sensed data and GIS can be efficiently used to detect the effects and damages of landslides by generating the causal thematic layers. This paper depicts the landslide based on the analysis on a case study which aimed to identify landslide potential zones in Coonoor Taluk of Nilgiris in Tamilnadu. The various causal factors responsible for landslide occurrence are slope, aspect, lithology, structure, lineaments, land use and land cover, drainage density, geology, geomorphology, soil and anthropogenic activity.

**Keywords:** GIS, Remote sensing, Landslide hazard zonation.

## INTRODUCTION

A disaster may be defined as “an event” concentrated in time and space which threatens a society or a relatively self-sufficient sub-division of a society with major unwarranted consequences as a result of the collapse of precautions**.**[1] Various disasters like earthquake, landslides, flood, fires, tsunamis, volcanic eruptions, and cyclones are natural hazards that kill lots of people and destroy property and infrastructure. The rapid increase in the population hazardous area, unstable lands, deforestation, improperly constructed buildings leads to vulnerable disaster. These disasters are the major challenges for the nation and the world. The percentage of deaths due to disaster is more in the developing countries comparing with developed countries. Nearly 95% of deaths due to disaster happen only in developing countries. In the same way, the property loss due to disaster is 20 times greater in developing countries comparing with developed countries. In these serious situations**,**the protection of life (human and animal), property and the infrastructure necessary for mitigation are the challenges world faces. Any delay in this disaster relief could increase the damages for the victims.[2]

Landslides are the major natural disaster, as the extreme rainfall event in Uttarakhand in June 2013 was without doubt the most deadly multiple landslides. The twin debris flows that struck the temple at Kedarnath were the defining event of the disaster, with a very complicated origin. Advanced disaster management technology like Remote sensing and GIS could provide a critical support system for disaster management authorities at this time of disaster-related crises.

### Disaster Management

Disaster management is the effort of communities or businesses to plan for and coordinate all personal and materials required to either mitigate the effects of, or recover from, natural or man-made disasters**.** Disaster management cannot stop or eliminate the hazards, although they can reduce the impacts and damages. Disaster management events can be implemented in natural disasters, public disorder, and industrial accidents. In Disaster management, the aim of the authorities are to view the situation, simulate the disaster occurrence area as accurately as possible in order to come with better predication methods, suggest appropriate plans and prepare spatial databases. Remotely sensed data can be used very effectively for quickly assessing severity and impact of damage due to, earthquakes, landslides, flooding, forest fires, cyclones and other disasters. With the GIS and Remote Sensing, areas vulnerable to both natural and man-made disasters along with their varying degree of vulnerability can be established and can be updated.

### Disaster MANAGEMENT, GIS and remote sensing

A Geographic Information System (GIS) is a powerful set of tools for collecting storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. In GIS, any area can be suitably represented into a vaster image of vector form. During the disaster prevention stage, GIS is used in managing the huge levels of data required for vulnerability and hazard assessment. In the disaster preparedness stage, it is used for planning rescue routes, making emergency operations centers and for emergency warning systems by using the satellite data integrating with other relevant data. In the disaster rehabilitation stage, GIS is used to organize the damage information and post-disaster census information and in preparing sites for reconstruction. Remote Sensing is the science and art of gathering information about an area, object or phenomena with the help of a sensor that is not in physical contact with the area or object under investigation. The application of remote sensing and GIS has become a well-developed and successful tool in disaster management, as we have our location observation programs and the requisite for hazard mitigation and monitoring rank high in the planning of new satellites.

**DisasterMapping**

Disaster mapping is the drawing of areas affected by natural or manmade disasters. It is normally possible to define the area affected by the disruption. The delineation can occur through the use of ground-based observations or through the use of remote sensing devices such as aerial photographs or satellite images. From the information gathered, it is possible to map the affected areas and provide information to the relief authorities. Disaster mapping is a tool for assessing, storing and conveying information on the geographical location and spread of the effects, or probable effects of disasters. The difficulty with traditional manual maps is that they are tedious and time consuming to prepare, difficult to update and inconvenient to maintain. Under remote sensing techniques, maps can be prepared using satellite data or aerial photographs and then digitized and stored on computers using GIS software. Disaster maps generally show risk zones as well as disaster impact zones. These are marked areas that would be affected increasingly with the increase in the magnitude of the disaster. These could include landslide hazard maps, flood zone maps, seismic zone maps, forest fire risk maps, industrial risk zone maps etc.

**Landslides**

Landslides are simply defined as the mass movement of rock, debris or earth down a slope and have come to include a broad range of motions whereby falling, sliding and flowing under the influence of gravity dislodges earth material. They often take place in conjunction with earthquakes, floods and volcanoes. If the movement of material is slowly down, then it is called as Land Erosion. In hilly regions, landslides constitute one of the major hazards that cause losses to lives and property. In general landslide activity is related to the following factors. Slope, geology, structure, lineament, geomorphology, rainfall and land use. The principal factors that initiate landslides are heavy and prolonged rainfall, cutting and deep excavations on slopes for buildings, earthquake shocks and tremors widespread deforestation and population pressure. The landslide hazards, in general cannot be completely prevented. In order to reduce the enormous destructive potential of landslides and to minimize the consequential losses, it is necessary that the hazard must be recognized.

Landslide analysis is a complex analysis, involving multiple of factors and it needs to be studied systematically in order to locate the areas prone for landslides. This requires spatial and temporal data related to the region. Remote sensing provides the spatial data at regular intervals, while GIS is a very fast and accurate method for analyzing and integrating various landslide triggering factors in a large volume.

**Landslides mapping**

Landslide hazard zone mapping involves a detailed assessment and analysis of the past occurrences of landslides in conditions of their location, size and incidence with respect to various geo-environmental factors. Landslide hazard zonation map included a map separating the draw out varying degrees of predictable slope stability. The map has an inbuilt factor of forecasting and hence is of probabilistic nature. Depending upon the methodology adopted and the comprehensiveness of the input data used, a landslide hazard zonation map is able to provide help concerning some other individual factor maps:

- Landslide location
- landslide Inventory
- Slope
- Aspect
- Lithology and Structural
- Geomorphology
- Soil
- Drainage Density
- Land use/ land cover
- Lineament Density
- Rainfall
- NDVI
- Transport
- landslide susceptibility

Preparation of an inclusive landslide hazard zonation map needs intensive and continued efforts. A huge quantity of data on lots of variables covering large slope areas has to be collected, stored, sorted and evaluated. Finally, the level of risk sliding has to be assessed and zonation maps prepared. The use of aerial photographs, satellite images and adoption of remote sensing techniques helps in the collection of data. For storage, retrieval and analysis, adoption of computerized techniques would be useful. In order to prioritize the area for hazard mitigation efforts, it is beneficial to have a LSZ map prepares depicting the ranking of the area based on actual and/or potential threat slides in future.

Here a case study for Coonoor on landslide and Land Erosion Mapping for Coonoor Taluk, Tamilnadu using Remote Sensing and GIS is illustrated to understand the mapping concepts for disaster mapping of landslides.

**Landslide OF COONOOR Taluk**

**Coonoor taluk location**

Land slide and land erosion mapping of Coonoor Taluk. It is located in Nilgiris district, a mountainous terrain in the NW part of Tamil Nadu, India. The area is between**11.27□N to 11.39□N** latitudeand 76.67 □E to**76.87 □E** Longitude.The headquarters of the taluk is the town of Coonoor, popularly known as Tourist Resort. It is nestledatan altitude of 1850 meters above Mean Sea Level and study area covers about 187sq.km.

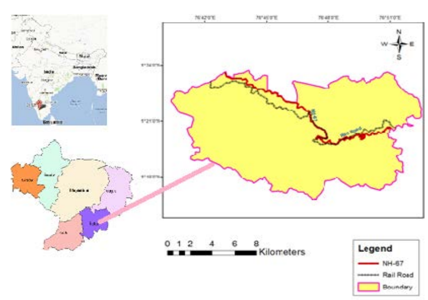



Fig. 1 Location of Coonoor taluk

**Landslide Inventory Map**

Landslide inventory maps show locations and characteristics of landslide that have moved in the past. Landslide inventory map provide useful information about the potential for future land sliding. The purpose of this mapisto identify the influence of different mes on landslide. In addition recognizing the type and recency of land sliding and guide slope remediation strategies.

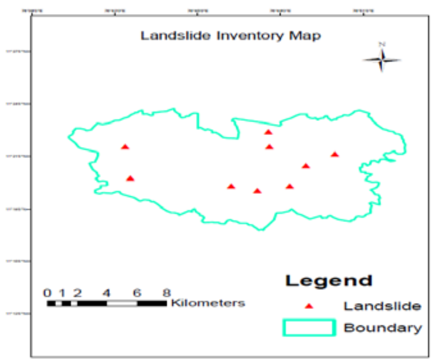



Fig.2 landslide inventory map

**Slope map**

Slope is an important factor in the analysis of landslide. As the slope angle increases, the shear of the soil Increases. So the probability of the occurrence of landslide increases. The slope class was categorized into 5 classes. The very steep slope is found in North western region. But the Landslide inventory map shows that most of the land slide occurred in moderate slope.

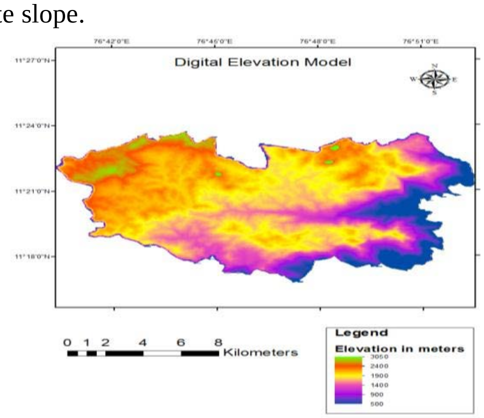



Fig.3 Digital Elevation model

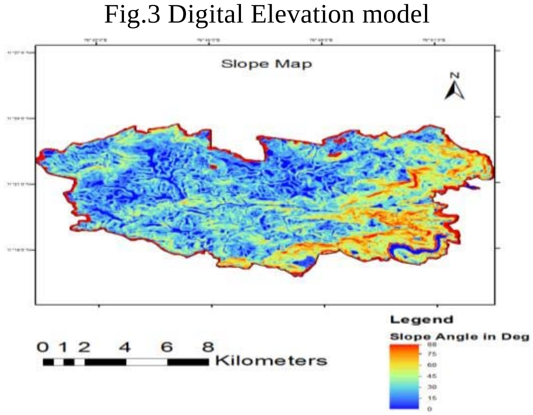



Fig.4 Slope map

**Aspect map**

As lope aspect map, which shows direction of slope. The related parameters of aspect such as exposure to sunlight, drying winds, rainfall and discontinuities may control the occurrence of landslides. More landslides occurred in North western and south western direction.

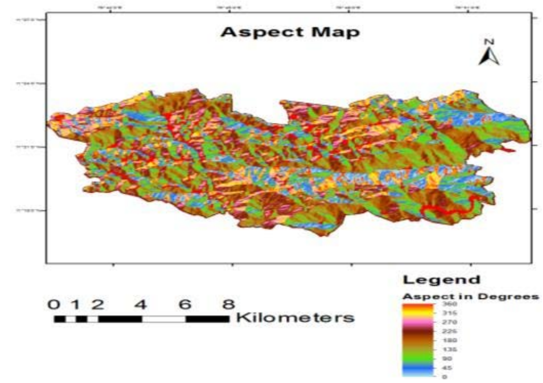



Fig.5 Aspect map

**Lithology and Structural Map**

Structurally the area is highly disturbed and subjected to faulting. The area is entirely covered by charnockite with banded Dolerite and magnetite. The Bearing capacity of charnockite is high. So it is less susceptible to landslide. Banded Dolerite is the indication of presence of fault.

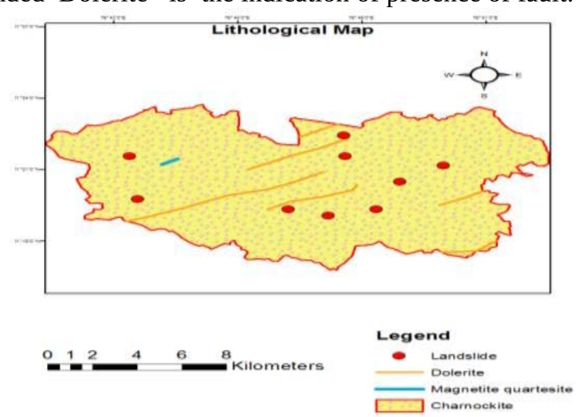



Fig.6 Lithological map

Structural Density map has been categorized into4 classes. More existing landslides occurred in less density area.

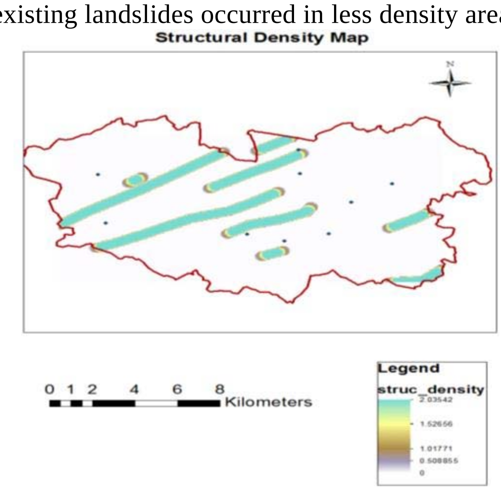



Fig.7 Structural Density map

**Geomorphology Map**

Geomorphology is the scientific study of landforms and the processes that shape them. This area is divided into highly (78.41 sq.km) and moderately (109.57 sq.km) dissected plateau. More existing landslide occurred in highly dissected plateau.

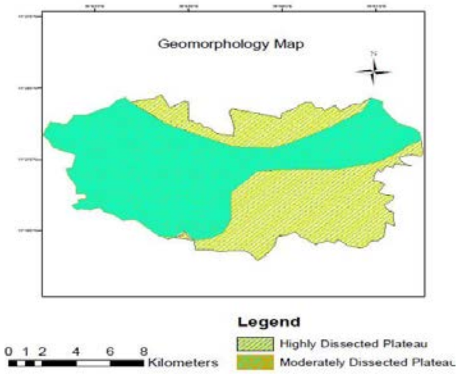



Fig.8 Geomorphology map

**Soil map**

This area has three types of soil namely Black clay soil (23.49sq.km), sandy loam red soil (51.21sq.km) and Brown clay loamy soil (112.70sq.km). Brown clay loamy soil is excessively drained and was found very high in the central and eastern side of study area.

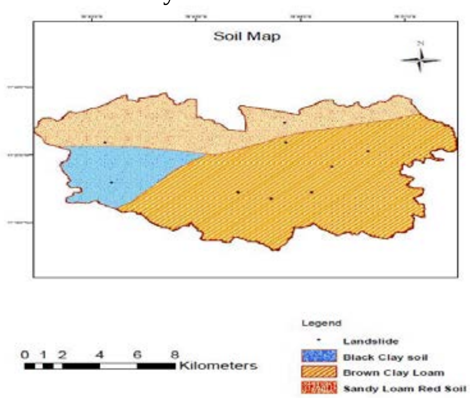



Fig.9 Soil map

**Drainage Density Map**

The drainage density map shows the flow of water throughout the area. Drainage density is defined as total stream length per basin area. The drainage density is an important factor as rainwater percolates in areas with low drainage density. As the distance from the drainage line increases, the probability of occurrence of landslide also increase. The drainage density for the study area was categorized into four zones (very high, high, medium and low).

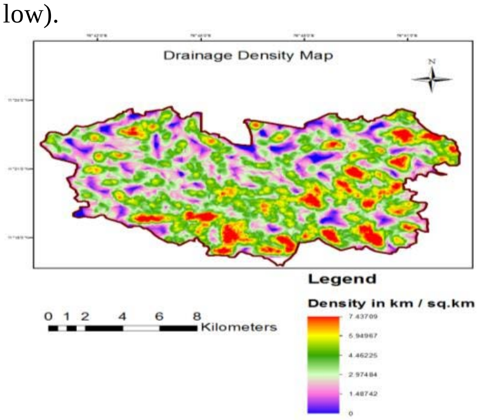



Fig.10 Drainage Density map

**Land use map**

The land use pattern of any terrain is a reflection of any complex physical processes acting upon the surface of the earth (Dai, etal.2002).The Land use map shows the different types of land cover pattern present in the area and modification of natural environment into built environment such as fields, pastures settlements. The area is characterized by the dense forest, agricultural land, plantation (tea & horticulture), barrenl and, scrub and built-up area. The Teaplantation is found as the major land use in the area.

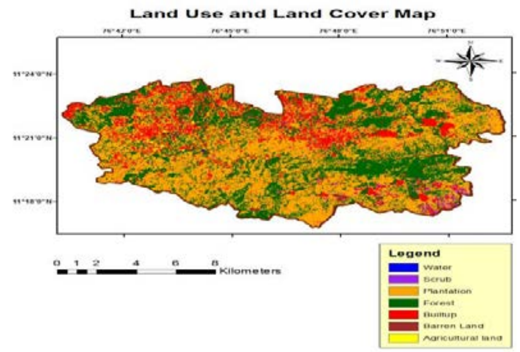



Fig.11 Land Use and Land Cover map

**Lineament Density map**

The lineament map shows the lineaments formed in the study area due to the geological conditions. Water flows through the cracks and the soil over this lineament would slide and hence this triggers the landslide. A lineament map was prepared by visual interpretation of the satellite data by identifying linear features. The lineament density is categorized into four classes as very high, high, moderate and low.

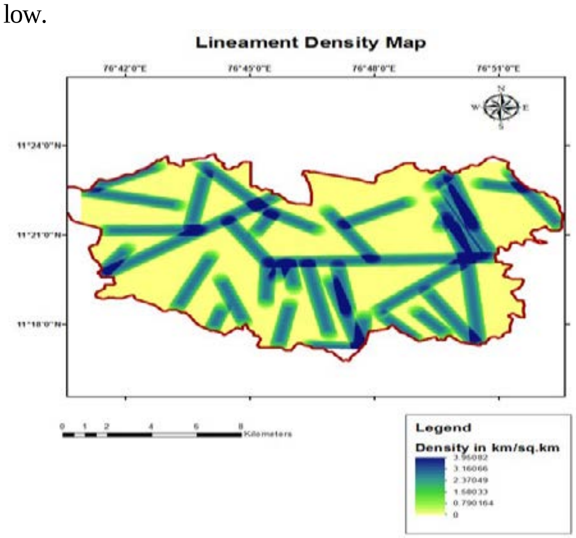



Fig.12 Lineament Density Map

**Rainfall map**

This area has four rainfalls station namely Aderly, Coonoor, Runneymedu, and Ketti. Rainfall data collected for years from statistical department, Ooty has been used to calculate the average rainfall intensity for each station.

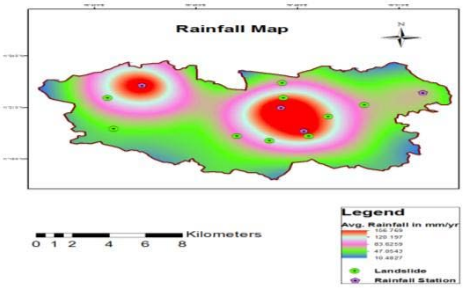



Fig.13 Rainfall map

**NDVI map**

A Normalized Difference Vegetation Index (NDVI) is an equation that takes into account the amount of infrared reflected by plants and used to analyze vegetation cover. Vegetation cover is an important factor which influences the occurrence and movement of the rainfall which triggers the landslide. Deforestation leads to land erosion. Normalized Difference vegetation index Map has been prepared from IRSP6satellite imagery using spectral enhancement technique available in ERDAS 9.1.Vegetated areas will yield high index values, because of their relatively high near IR reflectance. Rock and bare soil areas yield near zero values(0.0178). Built up yield near zero index values ranging between zeros to high positive values (0.0178 to 0.28). Water yield negative index values (-0.025).

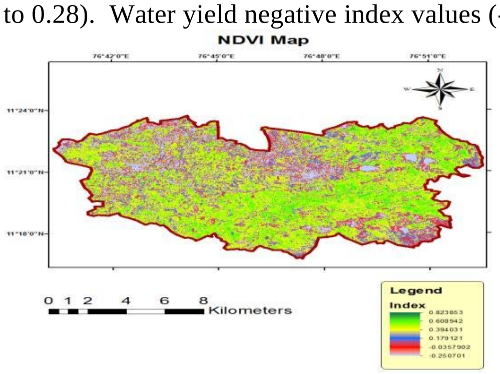



Fig.14 NDVI map

**Transport map**

Transport map has been prepared from SOI Topographical map by digitizing features such as road and railway track and up dated with satellite imagery. Transport density map is prepared from transport map. If transport density is more, it indicates the presence of cut slopes over which landslide and erosion will occur. Due to heavy traffic, vibrations also lead landslide and erosion. Usually, during rainy season NH-67 and railroad are greatly affected by the slide.

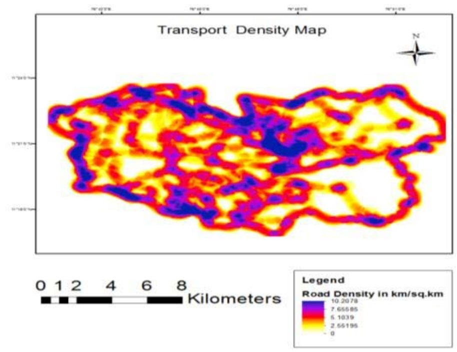



Fig.15 Transport Density map

**Landslide Susceptibility Map**

Landslide susceptibility map can be prepared by assigning weightage and ranking for each class of each theme. Weight age and Ranking has been assigned to each class based on their influence on landslide and land erosion. The influence of each class of each theme has been identified using landslide inventory map. Based on their influence on landslide and erosion, criterion table has been formed.

TABLE I: Criterion Table

| Themes | %Influence | Very High(4) | High(3) | Moderate(2) | Low (1) |
|---|---|---|---|---|---|
| Slope | 10 | 44-66 | 22-44 | 66-88 | 0-22 |
| Aspect | 6 | 270-360 | 180-270 | 90-180 | 0-90 |
| Geology | 2 | - | - | - | Charnockite |
| Geomorphology | 10 | Highly Dissected | Moderately Dissected | - | - |
| Soil | 10 | BrownLoamy | RedSandy | BlackDay | - |
| DrainageDensity | 10 | 5.6-7.4 | 3.7-5.6 | 1.8-3.7 | 0-1.8 |
| Lineament Density | 3 | 0-0.98 | 2.9-3.9 | 0.98-1.9 | 1.9-2.9 |

| | | | | | |
|---|---|---|---|---|---|
| Structural Density | 3 | 0.-0.5 | 1.5-2 | 1-1.5 | 0.5-1 |
| LandUse/Land Cover | 11 | Plantation, Builtup | Forest,Scrub | Agri.,Barren | Water |
| NDVI | 11 | 0.017-0.286 | -0.25-0.01 | 0.286-0.555 | 0.555-0.813 |
| Rainfall | 12 | 120-156 | 83-120 | 47-83 | 10-47 |
| Transport Density | 12 | 7.6-10.2 | 5.1-7.6 | 2.55-5.1 | 0-2.55 |

The percentage influence is multiplied with the weight of individual classes. There sultant weighted thematic maps have been overlaid and numerically added to generate a Land slide Susceptibility Index (LSI) map.

## RESULTS AND DISCUSSION

A landslide hazard zonation map indicates relatively potential zones such a slow, moderate, high and very high for landslide occurrence. This landslide and land erosion map shows that very high susceptible areas are largely found in northern part and high susceptibility areas are found in western part of study area. Moderately susceptible areas are largely found in south eastern part and low susceptible areas are found in North eastern and south western part of study area. Areas namely Katteri, Keti, Runneymedu, Yelanahalli andNH-67andRailroadjunctionarefoundinVery high and high susceptible Zones.

TABLE II

| Susceptible Zone | Area(sq.km) | Area (%) |
|---|---|---|
| Very high | 22.49 | 12 |
| High | 18.74 | 10 |
| Moderate | 103.09 | 55 |
| Low | 43.11 | 23 |

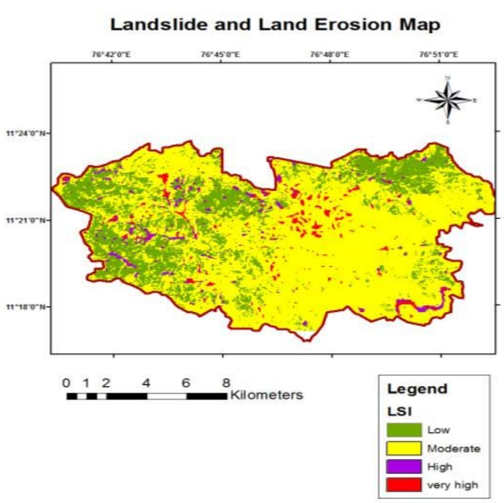
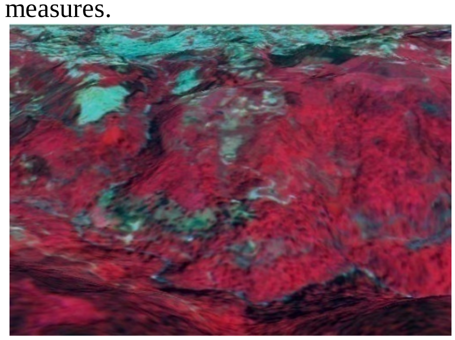



Figure16.LandslideandLandErosionMap

Heavy rainfall is the major factor leading landslide and land erosion. 60.13% of study area is covered with brown clay loamysoil. Because of heavy rainfall, pore water pressure will increase and shear strength of soil will be reduced. The vibration due to heavy traffic is an important factor for landslides and land erosion along the road. The heavy vehicles should be controlled during rainy season. Landslides are more frequent in areas with tea plantation. Due to increase in population and construction of roads on cuts lopes, deforestation also leads landslide and land erosion, which can be identified using NDVI analysis. A replanting programme should be undertaken giving priority for strong and deep rooted species which check erosion and withstand water-logging. Drainage density exerts a great influence on landslide susceptibility as erosion action of the streams is the main cause for slope instability and areas with high drainage density are found to be unfavorable. Majority of the landslides have occurred close to I and II order streams and hence, the incipient erosion taking place in the hills is one of the reasons for slope failure. More landslides and landerosion have occurred in highly dissected plateau of the study area. Hence, Geomorphological characteristics of this area are the one of the factors triggering landslide and land erosion. Landslides are not encountered in steep slopes as the charnockite which occur in such areas are massive and less jointed. Rock falls are very rare in the area.

**3D Visualization**

3-D visualization has been made using elevation Model created from contour map and IRSP6LISSI Vimagery in Virtual GIS Module available in ERDAS 9.1.This 3Dview will help us to analyze Landslide and land erosion susceptibility zone and to identify suitable mitigation measures.



## CONCLUSION

With the advancement in Information & Computation Technology (ICT) in the form of the Remote Sensing and GIS, a great deal of help can be had in the planning and implementation of disaster risk reduction measures. This paper brings out a definite relationship between the Remote Sensing and GIS techniques, which play a significant role in landslide and land erosion mapping. Landslide identification, which is a crucial parameter for any regional landslide hazard assessment, can be well done particularly with satellite remote sensing data. Coupled with remote sensing, GIS is an excellent tool to display the spatial distribution of landslides along with the irattributes. Planning in hazardous terrain involves developing policies and practices that mitigate the effects of hazard. This map provides sound basis for strategic and regional planning aimed atmitigating the effects of threatening landslide events. They are of great value to development planning as they present a spatial division of ground into areas of different levels of potential threat. It provides essential framework for land use planning, building regulations and engineering practices. An integrated approach using scientific and technological advances should be adopted to mitigate and to manage natural hazard. Moreover there should be a national policy for natural disaster management. Overall "Prevention is better than cure".

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