EVALUATING GEO-ASPECTS IMPLICATIONS ON LAND SLIDING IN HIMALAYAN TERRAIN IN A PART OF AIZWAL DISTRICT, MIZORAM STATE USING REMOTE SENSING AND GIS

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KEY WORDS: terrain parameters, landslides, remote sensing and GIS, Himalayas

ABSTRACT

Geology and geomorphology have a dominant control in the evolution of geo-aspects of a region. Remote sensing is an important and effective aiding tool in geological- geomorphological mapping in the Himalayan region where major parts of the terrain are inaccessible. Remotely sensed images provide a wealth of information, which permit evaluation of regional geological structures, broad lithological discrimination and spatial distribution of landforms. The study area lies in the Aizwal districts of Mizoram state. It is located between 92° 37' 30''E to 92° 45' 00'' E longitudes and 23° 40' 00''N to 24° 00' 00'' N latitudes and measures for about 472 sq. km in the Survey of India topographic sheets 84 A/9 and 84 A/10. Aizwal is the major township of the area. In this region severe erosion and concomitant land sliding in rainy season constitutes the main geo hazard. In the present work various terrain parameters viz.; lithology, geomorphology, landuse-landcover, slope, aspect, drainage, lineaments, roads are analysed with reference to landslides carried out using IRS LISS-III and PAN merged satellite images on 1:25,000 scale. The study demonstrates the use of remote sensing and GIS in evaluating geo-aspects implications on land sliding in Himalayan terrain.

1.1 Introduction

The term landslide refers to soil or rock materials movements / slips down the slope under the direct influence of gravitational forces. The movement could be different in terms of their shape, size, and origin depending on the terrain condition and triggering actions. The area selected for the present study exhibit severe erosion and concomitant land sliding in rainy season.

The study area (Fig1) comprising of hilly region with rugged terrain forming a part of Tlawng catchment lies in the Aizwal districts of Mizoram state. It is located between 92° 37' 30''E to 92° 45' 00'' E longitudes and 23° 40' 00''N to 24° 00' 00'' N latitudes and measures for about 472 sq. km in the Survey of India topographical sheets 84 A/9 and 84 A/10. Aizwal is the major township of the area. The National Highway (NH-54) passes through the area.

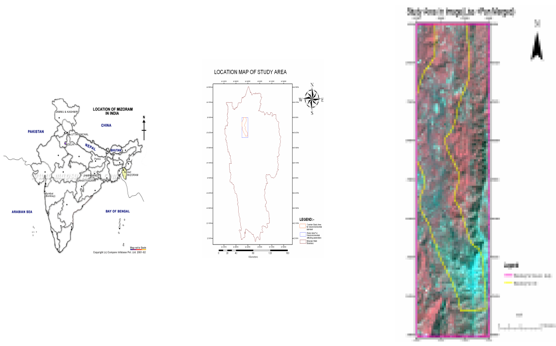

Figure 1 Location map of the study area

Geology and geomorphology have a dominant control in the evolution of geo-aspects of a region, which to a greater extent exert prime control in inducing land sliding in the region.

In the present study various terrain parameters like lithology, lineament, geomorphology, slope, aspect, landuse-landcover, drainage and road are analysed with reference to landslides to assess susceptibility of the terrain in inducing land sliding. Active landslides were demarcated in the area, using high-resolution remote sensing data of IRS-1D LISS III and PAN merged satellite data of February 2003. A total of 94 active landslides were identified. The spatial distribution of landslides over various terrain factors was calculated to understand the main factors of land sliding.

In the recent past various authors attempted GIS based landslide hazard zonation in Himalayan region by establishing relationship between terrain parameters and land sliding.

Sarkar S and Kanungo D.P. (2002) studied landslides in relation to terrain parameters using remote sensing and GIS approach in Dharjeeling area. Three terrain parameters viz; drainage, lineament and road have been considered in an integrated manner to evaluate layer-wise influence on landslide occurrence.

Pandey, A.C. et al., (2002) studied landslides in relation to terrain parameters in Tehri dam and its environs in Garhwal Himalayas and prepare a landslide hazard zonation map using remote sensing and GIS techniques.

1.2 Methodology

Methodology followed in the study involves generation of thematic maps pertaining to various terrain parameters like lithology, lineament, geomorphology, landuse-landcover, drainage, contour, road and landslide distribution based on visual interpretation of satellite images together with topographical maps and other collateral data.

Thematic maps are digitized using in Arc- GIS 8.2 and brought to real world coordinate in polyconic projection. Contour layer is used in developing Digital Elevation Model (DEM) of the area and subsequently used in generating slope and aspect map. Lineament and drainage maps were used in generating lineament density and drainage density maps respectively.
The area statistics of various terrain parameters were computed in GIS followed by calculation of landslide density and landslide frequency for further analysis. The flow chart of the methodology is given in figure 2..

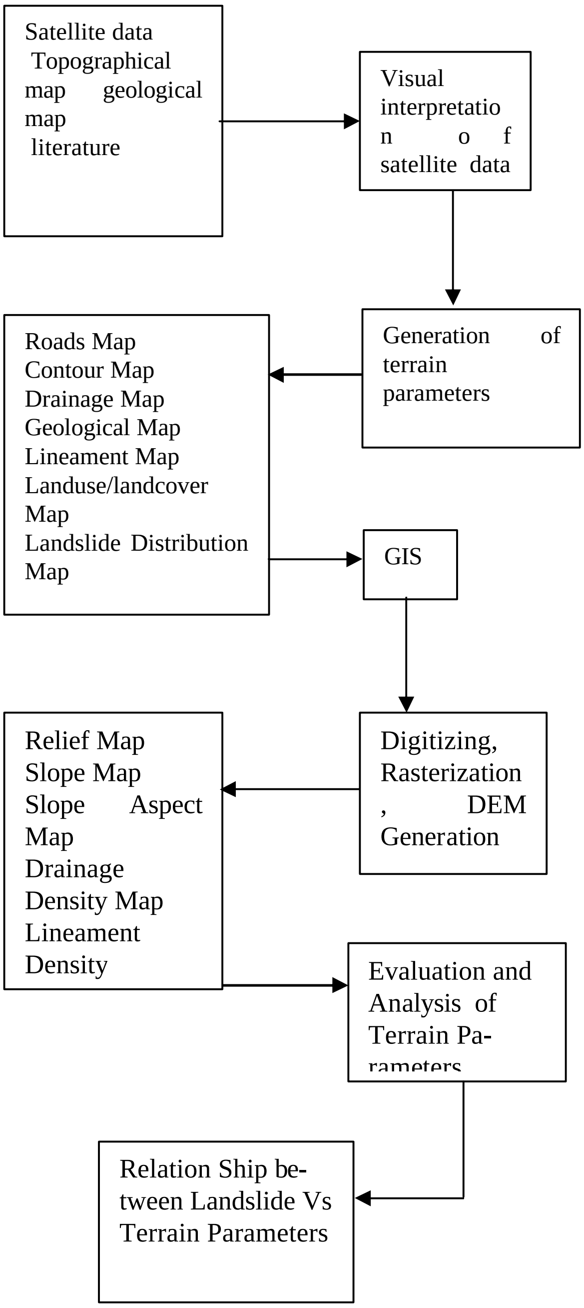

Figure 2: Flowchart of methodology

1.3 Results and discussion

The important aspect for detecting landslides using satellite imagery are their spectral characteristics, size, shape, contrast, and morphological expression. Visual interpretation of satellite images on 1:25000 scale together with image processing of digital satellite data was primarily attempted for locating landslides in the region (Fig. 3) and mapping lithology, liniments and landuse - landcover. The characteristics of high reflectance observed on active landslide due to their barren exposed surface together with their spoon and elliptical shape helped in demarcation of active landslides.

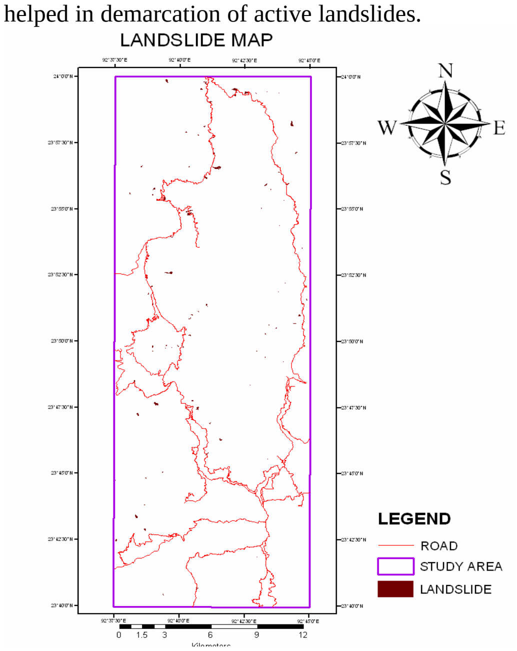

Figure 3 Landslide distribution in area along with road network

1.3.1 Relationship Between Terrain Parameters and Landslide Density

1.3.1.1 Lithology and Landslide Density

The density analysis reveals that the rock of Upper Bhuban formation (sandstone with shale) exhibit high landslide density as (0.003) as compared to other lithological units present in the area (Table 1 & Fig. 12). This suggests that the slope instability in the study area is largely influenced by the sandstone with shale association. The central and northern parts of area comprising sandstone with shale association, consisting of dense network of joints and traversed by number of major and minor faults exhibit large areas under active land sliding. Maximum number of landslides are located within the Upper Bhuban formation due to development of major roads through this formation making it a highly landslide prone zone (Fig. 4).

1.3.1.2 Geomorphology and Landslide Density

Geomorphology of the region (Fig 5) exhibit significant control in spatial occurrence of landslides and erosion pone areas and it portrays intricate relationship of lithology, structure, relief and climate. Landslide density analysis presented in Table 2 & Fig. 11 indicates that maximum landslide density as well as landslide frequency occurs in the areas, which are highly dissected. This is probably due to high rate of weathering and erosion in the dissected regions coupled with weak rock types. It is to remark that the numbers of observed landslides (83) are more in the moderately dissected hills due to their extensive aerial coverage in the area. Sand bar, river terrace and flood plain area due to their flat to very gentle slopes and low relief are devoid of any slope failure processes

1.3.1.3 Landuse-Landcover and Landslide Density

Among the forest types the landslide density values are highest in the forest blank followed by degraded and moderate forests and least in the dense forest (Fig 6). This is because in the dense forest the root systems is deep and dense, which increases the shear resistance of the mass through the creation of the negative pore pressure to increase soil cohesion. Landslide density in the non-forest area indicates highest values in the scrub land (0.0018) whereas in the settlements and cultivated land the landslide density values of 0.0010 and 0.0003 respectively are found (Table 3 & Fig. 13).

1.3.1.4 Slope and Landslide Density

The slope values ranging from 0 to 85 degree and classified into eight categories (Fig. 7) are integrated with the spatial distribution of landslide to determine the landslide frequency and landslide density in each slope class. A positive correlation exists between landslides and slope which indicate that areas with steep slopes are more prone to landslide occurrences (Table 4 & Fig. 14).

It has been calculated that higher values of landslide density has been observed in between 45°-55° slope (0.005) followed by 35°-45° slope (0.003) and lower values (0.002) corresponds to 5°-10° slope classes. This indicates that areas with steep slopes are more prone to landslide occurrences. The reason for no landslide occurrence below 5° is due to flat topography whereas areas belonging to slope class of greater than 55° comprises relatively less area wherein no landslides are observed (Table 4).

1.3.1.5 Aspects and Landslide Density

The highest landslide density exists on southeast facing slope (0.0026) and on northwest facing slope (0.0025) followed by south (0.0024) and west facing slopes (0.0025) (Table 5 and Fig 15). It is observed that aspect influence the micro climate in this hilly region and exert dominant control on vegetation (Fig.8). The aspects with high landslide density exhibit dominance of scrub, degraded forest and forest blank. It is therefore apparent that southeast facing and northwest slope aspect is having more probability for landslide occurrences.

1.3.1.6 Drainage and Landslide Density

A number of small landslides are seen along the drainage channels in the region, which owe their origin due to tow cutting by flowing water and steep slopes in the vicinity of river channel. The drainage density map (Fig. 9) was studied with respect to landslides in the region. It is been observed that landslide density is higher (0.002) in the high and moderate drainage density classes and lower (0.001) low drainage density classes (Table 6 and Fig 16). It can be remarked that higher drainage density indicates higher terrain dissection, more erosion and subsequently more land sliding in the region.

1.3.1.7 Lineament and Landslide Density

Lineaments in hilly terrain indicate joints, fractures, faults and other structural features of weakness (Fig. 10) and therefore bear a direct relationship with the occurrence of landslides. A number of active landslides are located in the zones of faults and major lineaments in the area. Lineament density map prepared (Fig. 11) by computing lineament density in 20m x 20m grid cell in the area indicate a positive correlation between landslide density and lineament density (Table 7 and Fig.17). Maximum landslide density (0.01) has been found in very high lineament density class followed by moderate-high (0.005) and least in low lineament density class (0.001). It points to the understanding that areas with more fracturing and faulting are always prone to occurrence of landslides.

1.3.1.8 Road Distance and Landslide Density

There exist a direct relationship between distance from the road and the occurrence of landslides (Fig 3). Density of landslide is highest in the proximity of roads and decreases away from it (Table 8 & Fig. 18). It is to remark that out of the total landslides delineated in the area about one forth are located along the roads. This emphasizes that the construction of roads contributed to a great extent in slope destabilization process.

1.4 Conclusions

Landslide frequency and landslide density was evaluated in relation to various geoenvironmental parameters to visualize relative susceptibility of different terrain parameters to landslide occurrence. It has been found that high spatial resolution satellite image obtained by merging IRS-1D PAN and LISS III data are quite useful for mapping different terrain feature including spatial distribution of landslides. GIS is found to be a useful tool for multilayer spatial data analysis. The result obtained from the study has shown a positive relationship between landslides and drainage density, which may be due to higher surface runoff and concomitant weathering and erosion. Rock types like shale and siltstone with high drainage density are more prone to land sliding causing instability in the area of their occurrences. Higher landslide frequency also corresponds to high lineament density indicating that the areas with high dissection due to presence of lineaments are more susceptible to landslides. The maximum landslide frequency within a range of 50m distance from the road corroborates the fact that construction of roads is one of the prominent anthropogenic activities leading to an increase in the occurrence of landslides..

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Table 1: Landslide frequency and density with respect to lithology classes

Lithological Unit	**Lithology**	**Lithological Unit Area (sq. km.)**	**Number of landslides/landslide frequency**	**Landslide Area (sq.km.)**	**Landslide density**
Bokabil Stage	Shale, Sandy shale and Siltstone	108.4826	17/0.156826	0.1912	0.0017638
Upper Bhuban Formation	Sand stone with shale	134.3184	38/0.282948	0.488904	0.0036403
Middle Bhuban Formation	Shale interbeded by sandstone	176.3224	27/0.153130	0.339	0.0019228
Lower Bhuban Formation	Sandstone with shale/siltstone	53.5238	12/0.224299	0.027083	0.0005362

Table 2: Landslide frequency and density with respect to geomorphology classes

Geomorphic Units	**Geomorphic Units Area (sq. km.)**	**Number of landslides / landslide frequency**	**Landslide Area (sq.km.)**	**Landslide density**
Low Dissected Hills	46.431623	7/0.1507645	0.054977	0.00119512
Moderate Dissected Hills	396.227933	83/0.209479	0.892612	0.0022529
High Dissected Hills	25.867972	4/0.3378378	0.102026	0.0032602
Sand Bar	0.096434	0/0	0	0
River Terrace	1.7422458	0/0	0	0
Broad River Valley / Flood Plain	2.479960	0/0	0	0

Table 3: Landslide frequency and Landslide density with respect to landuse/landcover classes

Landuse–Landcover (LU-LC) Category	**LU-LC Area (sq. Km.)**	**Number of Landslides / Landslide Frequency**	**Landslide Area (sq. Km.)**	**Landslide Density**
Dense Forest	306.028615	48/0.160130	0.373260	0.0012198
Moderate Forest	49.677025	16/0.322126	0.254173	0.0051172
Degraded Forest	55.647678	15/0.269784	.289574	0.005388
Scrubs	26.804377	9/0.3358208	0.049257	0.00183794

Forest Blank	2.918528	1/0.3436426	0.018951	0.00649451
Water Body/River	2.385963	0/0	0	0
Settlements	13.874093	1/0	00.0142716	0.001025
Shifting Cultivation	15.324538	4/0.2610966	0.050970	0.0003332

Table 4: Landslide frequency and density with respect to slope classes

Slope Classes (degree)	**Slope Class Area (sq.km.)**	**Number of landslides /landslide frequency**	**Landslide Area (sq.km.)**	**Landslide density**
<5°	29.04000	0/0	0	0
5°-10°	62.707500	14/0.2232854	0.129032	0.00205792
10°-15°	77.562500	20/0.2578648	0.183149	0.00236322
15°- 25°	166.302500	29/0.1746987	0.40253	0.00242050
25°-35°	106.837500	25/0.2340823	0.2585280	0.00243894
35°-45°	27.0575	5/0.18484288	0.090815	0.00336357
45° – 55°	3.4825	1/0.28735632	0.017489	0.0050255
>55°	3.86	0/0	0	0

Table 5 : Landslide frequency and density with respect to aspects classes

Slope Direction	**Slope Direction class Area (Sq. km.)**	**Landslide number /landslide Frequency**	**Landslide area (Sq.Km.)**	**Landslide Density**
North (0-22.5)	28.452500	4/0.14059753	0.0354199	0.001244
North-East (22.5-67.5)	54.415000	14/0.2573056	0.09436928	0.001734
East (67.5-112.5)	63.782500	13/0.2038256	0.02466359	0.000386
South – East (112.5- 157.5)	50.300000	8/0.15904572	0.13394358	0.002662
South (157.5-202.5)	43.310000	8/0.18471484	0.10531626	0.002432
South- west (202.5-247.5)	55.430000	10/0.1804077	0.11355668	0.002048
West(247.5-292.5)	87.300000	19/0.2176403	0.22192936	0.002542
North –West (292.5-337.5)	68.047500	15/0.2204585	0.17666008	0.002596
North (337.5-360)	29.015000	3/0.1034482	0.0120986	0.000418

Table 6: Landslide frequency and density with respect to drainage density classes.

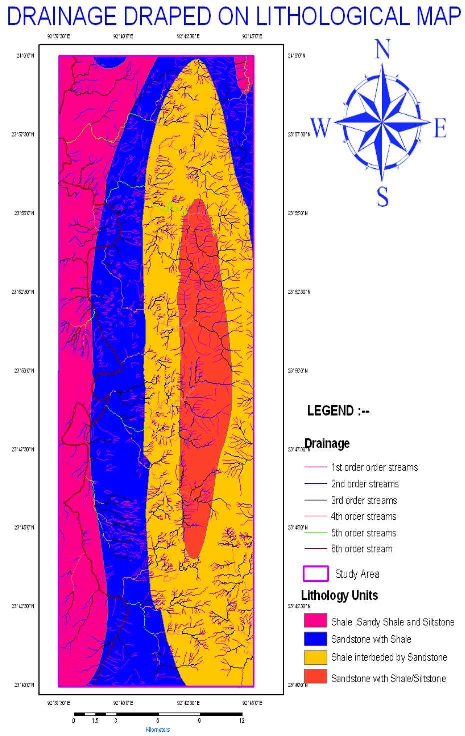
Drainage Density (km/Sq. km.)	**Drainage Density Class Area (sq. km.)**	**Number of landslides /l landslide frequency**	**Landslide Area (sq. km.)**	**Landslide Den-sity**
Low (0 - 0.01)	174.043200	18/0.1034482	0.23348068	0.0013415
Moderate (0.01 – 0.06)	295.236000	72/0.2439024	0.880982	0.0029840
High (0.06 - 0.1)	6.896400	4/0.58055152	.020278	0.0029431
Very High (> 0.1)	2.185200	0/0	0	0

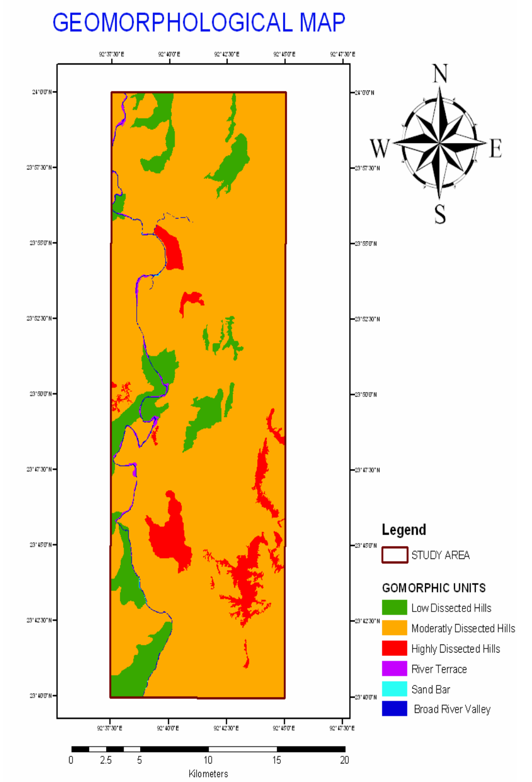
Table 7: Landslide frequency and density with respect to lineament density classes.

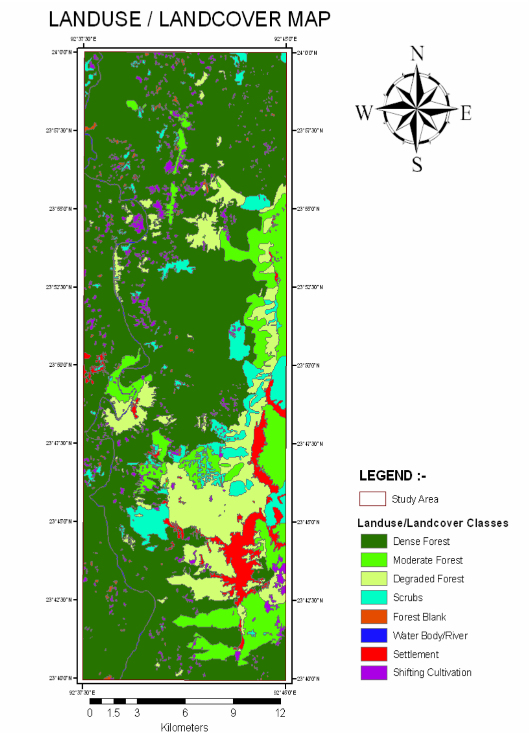
Lineament density (km/sq.km.)	**Lineament density class Area (sq.km.)**	**Number of landslides /frequency**	**Landslide Area (sq.km.)**	**Landslide Density**
low (0 -.02)	374.2892	64 / 0.170994	0.518668	0.001385
Moderate(002– 0.06)	54.6540	18 / 0.329368	.249544	0.00456
High (0.06 - 0.3)	43.8212	10 / 0.2282062	.233370	0.00532
Very High (> 0.3)	4.997200	2 / 0.40080160	.0620 96	0.01267

Table 4: Landslide frequency and density with respect to distance from the road

Road buffer (m)	**Road buffer Area (sq. km.)**	**Number of landslides/ Landslide Frequency**	**Landslide Area(sq. km.)**	**Landslide density**
0-50	22.45678	18 / 0.8017817	.261384	0.011774
50-100	20.08752	10 / 0.4980079	.220856	0.011624
>100	230.2	66 / 0.2867072	.56990	0.002468







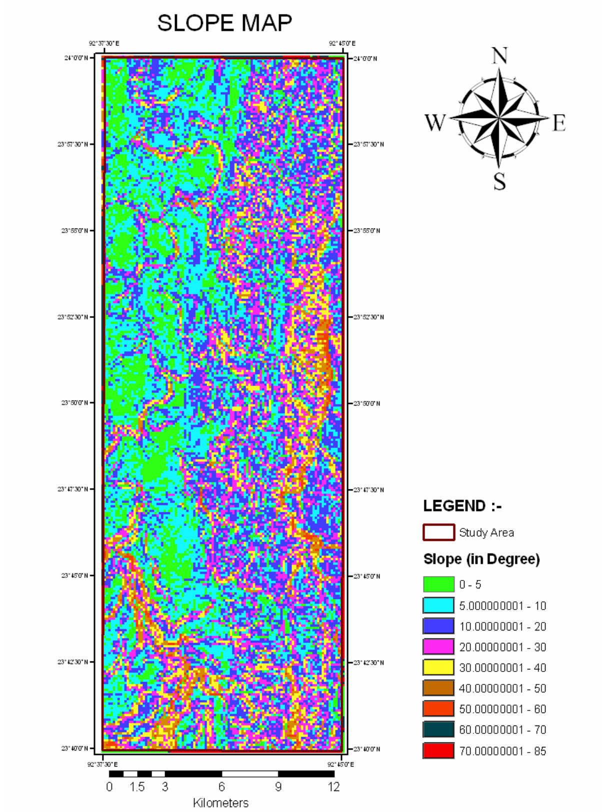


Figure 4 Lithological map Figure 6 Landuse - landcover map

Figure 5 Geomorphology map Figure 7 Slope map of the study area

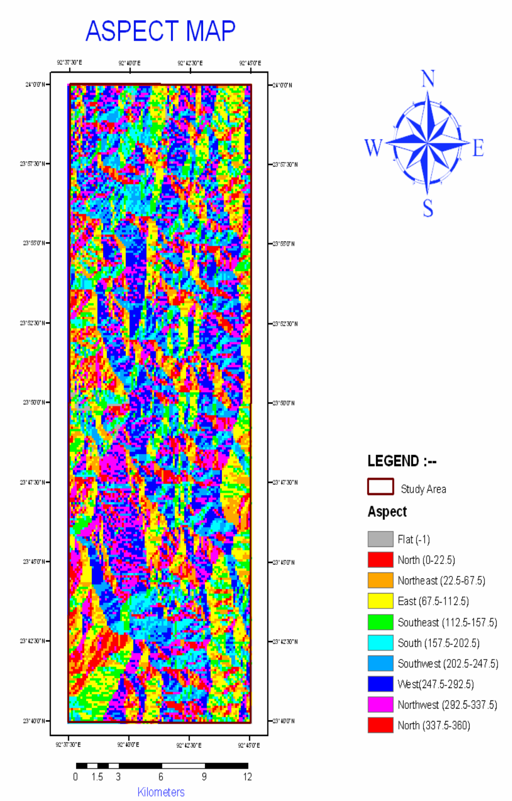


Figure 8 Aspect map

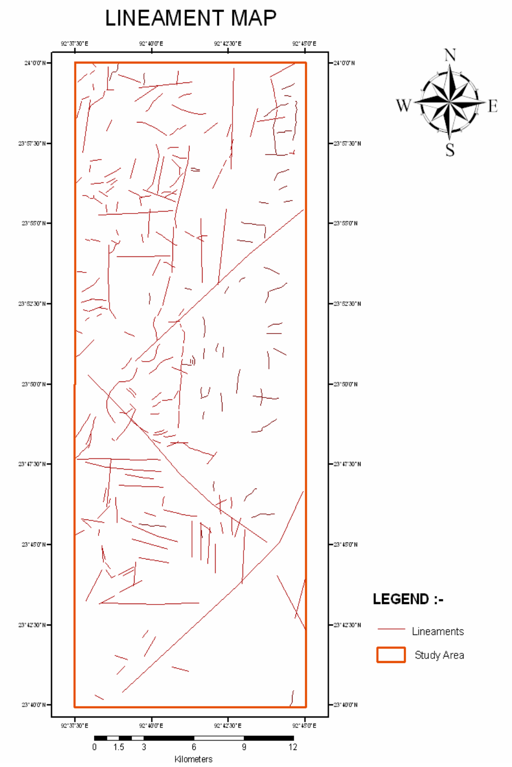


Figure 10 Lineament map

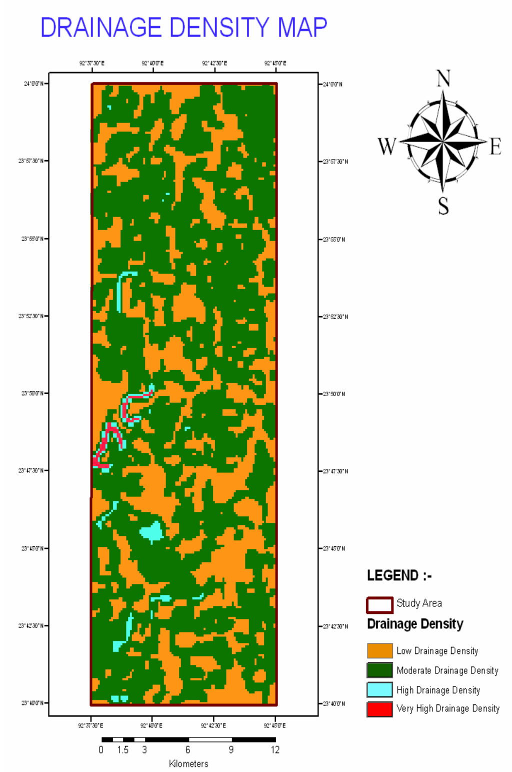


Figure 9 Drainage density map

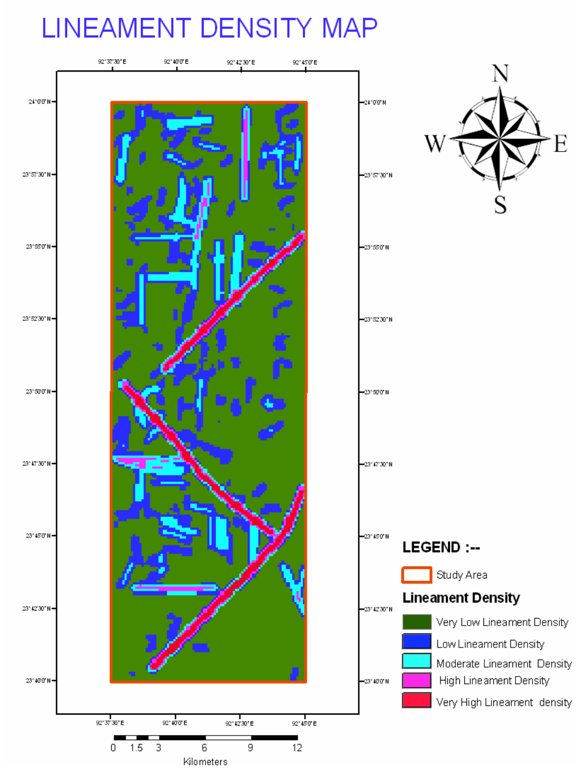
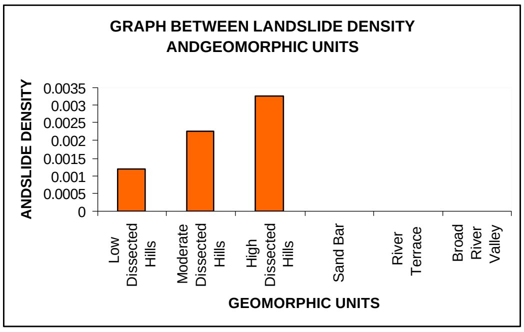


Figure 11 Lineament density map



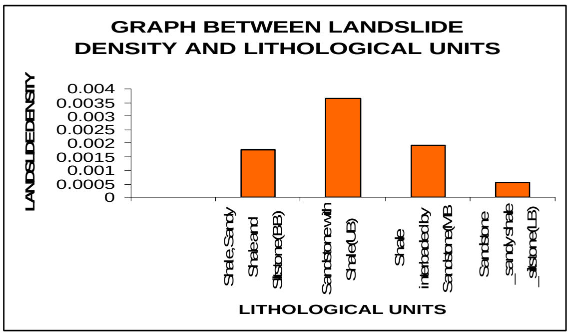
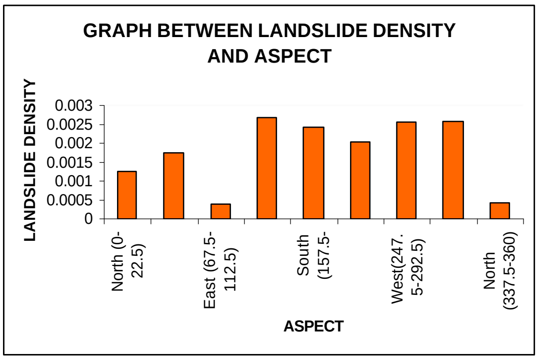


Fig. 11 Landslide Density Vs Geomorphology Fig. 12 Landslide Density Vs Lithology



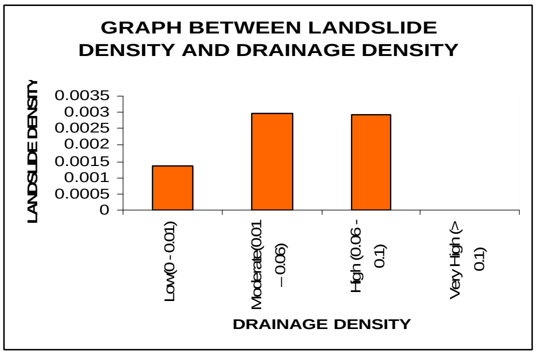
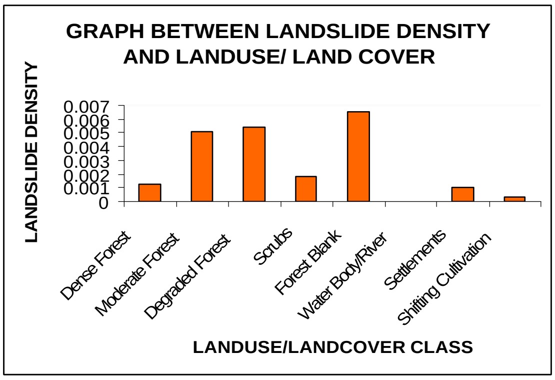


Fig. 15 Landslide Density Vs Aspects Fig. 16 Landslide Density Vs Drainage Density



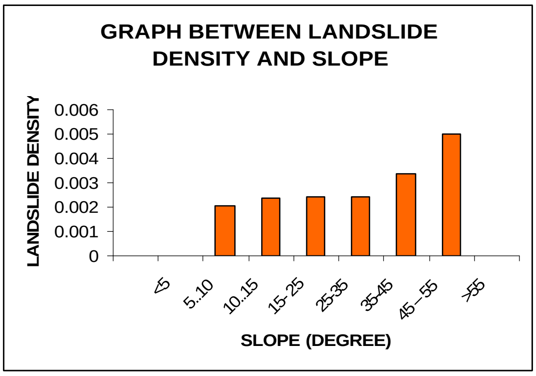
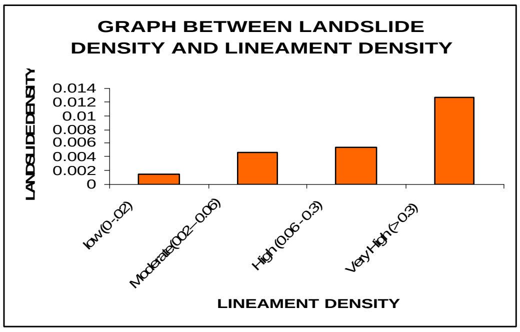


Fig. 13 Landslide Density Vs Landuse - Landcover Fig. 14 Landslide Density Vs Slope



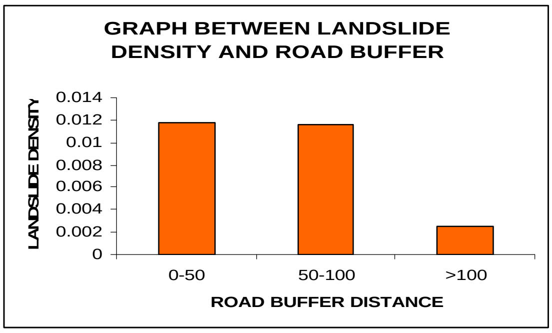


Fig 17 Landslide Density Vs Lineament Density Fig 18 Landslide Density Vs Road Buffer