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CASUSES AND CONSEQUENCES OF LANDSLIDE IN NILGIRIS

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ABSTRACT

A disaster is an unfortunate event caused by factors mostly beyond human control that often strikes suddenly and without notice, causing or threatening major disruption of life and property. The study for The Nilgiris district clearly reveals that even though many studies carried out on hazard zonation level however there is no detailed study on prediction of landslides. The landslide hazard zonation maps should be used properly and there should be a detailed investigation on individual slopes which is prone to landslides. It should include detail maps at planning level which can show development, existing landslide risk, and predicted new slopes where we can deploy the early warning system for slope failure based on past landslide locations. There is no early warning system followed in The Nilgiris district as per the study and one of the landslide related focus area for this district is development of landslide early warning systems.

KEYWORDS: *Disaster, Disruption, Nilgiris, Landslide, Hazard Zonation.*

1. INTRODUCTION

Natural hazards such as earthquakes, tsunamis, cyclones, floods, and other natural disasters are examples. A disaster can substantially disrupt a community's or society's functioning and result in human, material, economic, or environmental losses that are greater than the community's or society's ability to cope with using its own resources. Disasters can have human causes, even if they are often caused by nature. Disasters are very dangerous as they destroy development of infrastructure created over the years in different sectors. Affected countries are forced to go back to earlier stages of development. Thus, precious time, effort and money, which should have been devoted to development work, have to be devoted to rehabilitation and fresh investments to put the country 'back on tract'. Natural disasters impede economic and social progress.

Landslides are the most commonly occurring geological hazard worldwide and the next most frequent natural catastrophic event, after hydro-meteorological events (Moretti and Cigna 2012 Landslides must be caused by an amalgamation of causes, including earthquakes, heavy rain, geology, land cover, slope geometry, vegetation cover, groundwater saturation and human activities (Pradhan et al. 2011; Rawat and Joshi 2011). Landslide assessment is a method of analyzing risky areas that are vulnerable to landslides. Every year, landslides destroy infrastructure, inflict property damage, and result in thousands of human death and injuries (Saha et al. 2002; Guzzetti 2003; Akgu n and Turk 2010).

2. REVIEW OF LITERATURE

A review of published research works has been conducted to better understand landslide mapping, factors influencing landslides, geophysical survey and geotechnical studies in landslide studies, instrumentation and slope monitoring techniques, and forewarning for rainfall-induced landslides published by various authors throughout the world. A large number of the studies described in the literature use geomatics, geophysics, and geotechnical studies for landslide mapping, investigation, characterization, quantification, and forewarning. The following review summarizes work done in several countries around the world, and also a comparison of instruments and methods used in landslide investigations.

Sharpe (1938) defines a landslide as an observable movement involving a relatively dry quantity of earth material. A landslide is a loose or separated part of a slope or sloping mass that slides down a landslide.

Landslides, according to Vames (1984), are "almost all forms of mass movements on a slope, including some that entail little or no actual sliding, such as rock falls, topples, and debris flow." Landslides, according to Brusden (1984), are a unique form of mass transportation and a process that does not require the use of a transportation medium such as water, air, or ice.

"The outward and downward gravitational movement of the mass of the earth without the aid of flowing water as a transport agent," according to Crozier (1986). According to Hutchinson, a landslide is "a very fast mass wasting process that causes the downward slope motion of a mass of rock, rubble, or soil due to a variety of external stimuli" (1988).

Cruden (1991) defined it as the sliding of rock debris or dirt downslope. Since last few decades the term 'landslides' is being used to define mass movement, but it refers to only a specific type of slope movement with the specific composition, form and speed. According to Stewart et al. (2000), the phrase "mass movement" refers to any type of detachment and down-slope movement of soil and rock at various speeds. They also stated that landslides are defined as any mass movement that is faster than 1 millimeter per day.

3. AIMS AND OBJECTIVES

The aim of the study is to demarcate the landslide areas of Nilgiris district and to evaluate the impact and their vulnerability level on the tribal group.

- To observe the landscape of Nilgiris district.
- To examine the causative factors of landslide in Nilgiris district.
- To delineate the landslide prone zones in Nilgiris district
- To construct best model for assessing the landslide vulnerable zones.

4. DATA AND METHODOLOGY

The current research is based on both primary and secondary sources of information. The secondary data set comprises a satellite image of Landsat 8 OLI data, which was acquired by the USGS in March 2019. The State Ground and Surface Water Board, Taramani, provided monthly rainfall statistics for various locations in the Nilgiri district. EOSDIS has been used to download land use land cover for the Nilgiri district. The USGS has provided SRTM data with a resolution of 30 meters. The Geological Survey of India provided data on soil, soil depth, and lithology. Landslide data has been acquired from the Nilgiris district's Public Work Department for a landslide hotspot that occurred earlier. The Digital Elevation Model (DEM) in ArcGIS was used to construct slope and elevation models. Lineament, lineament density, moisture stress, and NDVI were all calculated using satellite imagery.

The landslide susceptibility study is carried out with the use of several layers of data gathered from various sources. The Analytic Hierarchy Process (AHP), Frequency ratio model, Binary logistic Regression model, and Shannon's Entropy are four strategies employed in this study to achieve more accurate results. These four strategies have been discussed briefly below. Furthermore, to find out more accurate landslide predicting zones, a susceptibility map has been formed with the help of the maps obtained by using these four techniques by overlaying each map together in ArcGIS software. The final map displays tribal settlements that are located in high-risk landslide zones. For primary data collection, the samples were chosen using a random sampling method and the snow ball sampling method.

5.1 LANDSLIDE HAZARD ZONATION MAPPING IN NILGIRIS

Landslides are the most commonly occurring geological hazard worldwide and the next most frequent natural catastrophic event, after hydro-meteorological events (Moretti and Cigna 2012 Landslides must be caused by an amalgamation of causes, including earthquakes, heavy rain, geology, land cover, slope geometry, vegetation cover, groundwater saturation and human activities (Pradhan et al. 2011; Rawat and Joshi 2011). Landslide assessment is a method of analysing risky areas that are vulnerable to landslides. Every year, landslides destroy infrastructure, inflict property damage, and result in thousands of human death and injuries (Saha et al. 2002; Guzzetti 2003; Akgu¨n and Tu¨rk 2010).

In a landslide assessment, the research area is split into various types of homogeneous areas, each of which is graded according to the likelihood of a landslide. The significance to a landslide assessment lies in the possible landslide-affecting factors (Pradhan, B. 2013; Rawat, J. S et al. 2012). Accordingly, the detection of landslide- affecting variables is critical. The happening of a landslide is the consequence of several sorts of forces acting together. Landslides are influenced by a numerous factor, including geological structure, topography, and landform along with hydro- meteorological conditions. Thus, the landslide vulnerable of the proposed study region was deeply assessed by utilizing 10 conditioning factors (i.e., rainfall, NDVI, lithology, soil, soil depth, lineament buffer, slope, LULC, aspect, lineament density).

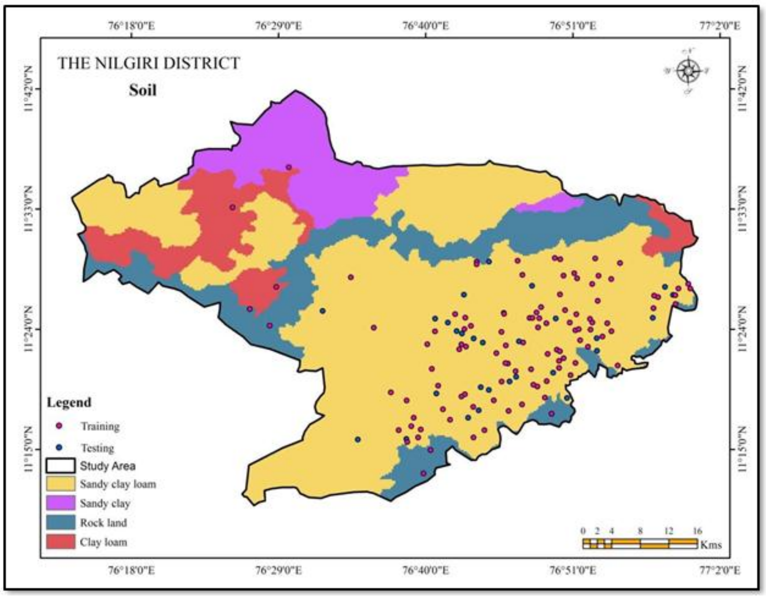
5.2 FACTORS ACCOUNTABLE FOR LANDSLIDE

Selecting the appropriate conditioning factors with significant contribution in the happening of landslide to produce a model is a challenge (Ayalew and Yamagishi 2005). In landslide susceptibility mapping, there are almost no general standards for factor selection. The factors selected for landslide susceptibility assessment in a GIS- based study must be operational, complete, non-uniform, fundamental, and measurable (Ayalew and Yamagishi 2005). Because of the above criteria, soil, soli depth, slope, aspect, rainfall, lithology, NDVI, land use land cover parameters, a total of ten potential predisposing factors were considered in this current study. A brief description of every presumed controlling factor is given below.

5.2.1 SOIL

Soil is an important causative factor responsible for landslide. The soil with more sand, instability slope and severe rainfall which constitute most dominant factor of landslide, cause stern damage to the land (Patanakango, 2001, Wieczorek et al., (1996) analyzed the effects of soil type on landslide incidence. The authors identified that the occurrences of landslide mostly on unconsolidated till and clay deposits.

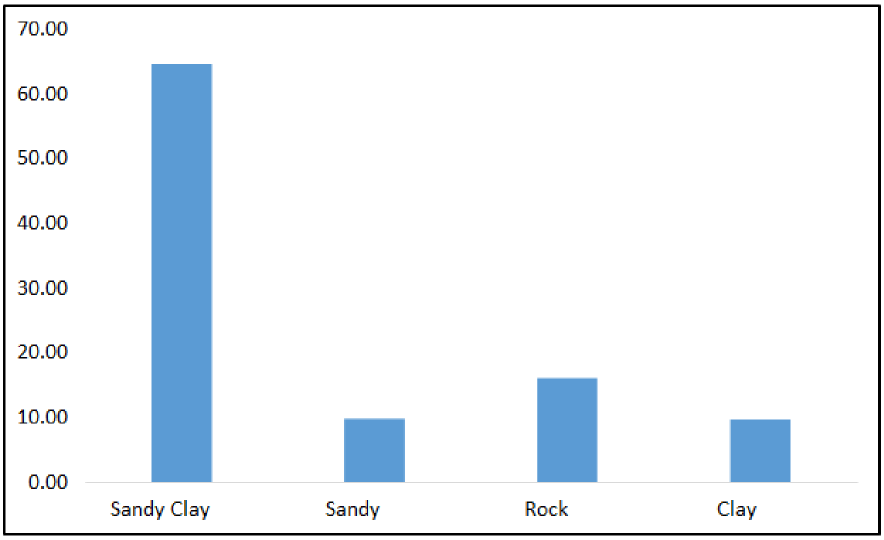
Figure 1.1 Soil Map



(Source: Geological Survey of India)

The soil map of the study area is given in figure 1.1 which shows that soil has been classified into four groups namely sandy clay loam, sandy clay, rock land and clay loam. Sandy clay loam can be seen from east to south, and also some patches are in north and western parts. Sandy clay is only visible in Northern region. Rock land starts from west and the chain move towards central region the ends in north-east. Rock land also can be seen in few parts of south and south-east. Clay loam is seen in western region, few parts of north and a small patch in eastern region. The most dominant class sandy clay loam which covers 1647.52 Sq.km which is 64.55% of entire district, subsequently the sand clay forms 248.88 Sq.km which is 9.75% of the district, rock land covers 409.73 Sq.km with 16.05% of the district, clay loam covers 246.37 Sq.km which is 9.65% of the district (figure 1.2).

Figure 1.2



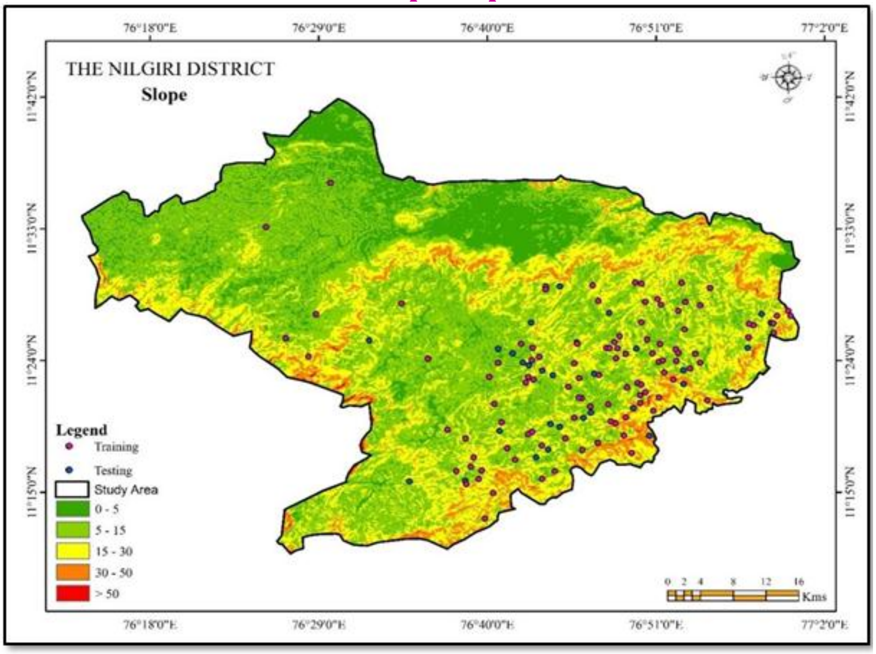
Spatial Distribution of Soil

(Source: Geological Survey of India)

5.2.2 SLOPE

Slope is a major important factor affecting slope stability (Anbalagan, 1992; Pachauri et al., 1998; Saha et al., 2002; Yaclchin, 2008) find this review) since the driving force of mass movement increases with increasing slope (Guillard and Zezere, 2012). Slope is the common factor which influences the slope stability. The research region's slope map (Fig. 4.5) spans from 0 to 50^0 degrees, with sharp slopes in the majority of the study area. Slope map is sorted into five classes viz., 0-50^0, 50^0-15^0, 15^0-30^0, 30^0-50^0 and > 50^0. The soil map reveas that the majority of the northern parts of Nilgiris district has 0-5^0 slope. 5^0-15^0 are seen in the major parts of western and few parts of central region. 15^0-30^0 slopes are in the eastern and southern regions, also in the border of the west region along with few in central parts whereas steep slope ranging from 30^0-50^0 can be seen few areas of west, covering much of the part of north eastern region and also towards the extremes of south-eastern regions. In Nilgiris the slope with >50^0 can be found very rarely to south-eastern. Such types of slopes can also be seen in south-western parts of rocky regions.

Figure 1.3
Slope Map



(Source: Geological Survey of India)

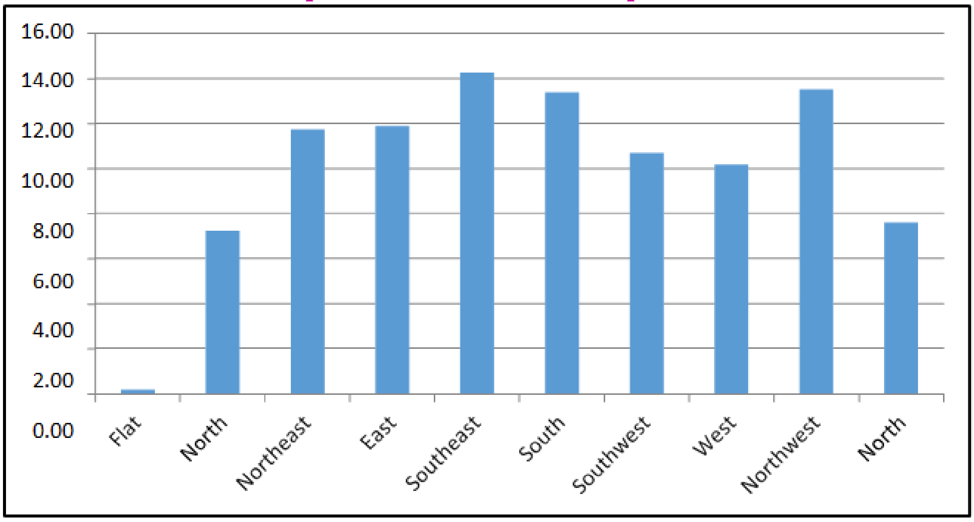
5.2.3 ASPECT

The aspect can influence landslide initiation. Water preservation and vegetation is intimated by slope aspect result to weakening the soil strength and influences of landslide. The aspect also plays important responsibility in controlling some microclimatic causes such as rainfall intensity, exposure to sunlight and windward (wet) or leeward (dry) conditions, soil moisture, and weathering all of which control the material properties of the slope deposits (Dai et al.,2001; Cevik and Topal, 2003). Aspect is analyzed as slope direction which controls solar insulation receives by the surface as average sunshine hour per day. Aspect is the crucial factor that induces slope instability.

The map in figure 4.7 shows the direction of the aspect in Nilgiris district. The area of flat region is minimum since the Nilgiris district is located in Western Ghats. Flat aspect is in the central parts. Majority of north and northeast aspects can be seen in central, eastern and extreme west of Nilgiris district. East and southeast aspect is visible in northwest and southeastern region of the study area.

Here the following graph in figure 4.8 reveals that only 4.32 sq km area which is 0.17 percent of total area of Nilgiris district has flat surface. Around 301.27 sq km area i.e., 11.80 percent has north facing aspect. Northeast aspect of Nilgiris has covered 297.99 sq km area which is 11.67 percent. Aspect from east covers an area of 301.27 sq km which is of 11.80%. Aspect facing Southeast direction covers 361.78 sq km of 14.17% of entire district. South direction of aspect covers 339.52 which is of 13.30%. Southwest facing aspect has an area of 270.86 sq km which is 10.61% of the Nilgiris district.

Figure 1.4
Spatial Distribution of Aspect



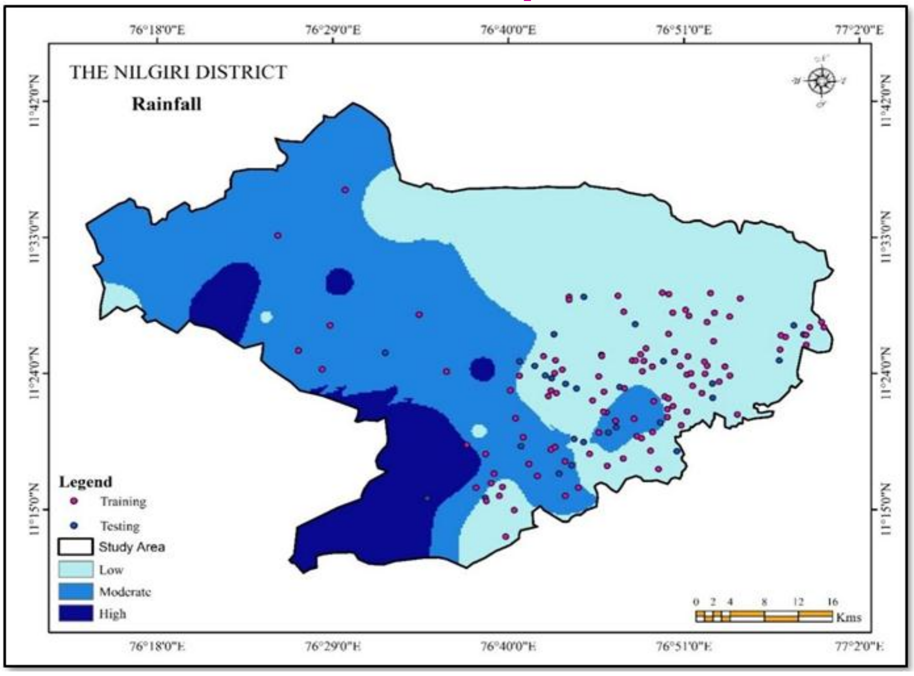
(Source: USGS, 2019)

West facing aspect is having 258.03 sq km area, which covers 10.11% of the district. Aspect having Northwest facing is 342.81sq km area, which is of 13.43% of the district. The north facing aspect has 192.61 sq km area and it covers 1.55% of Nilgiris district.

5.2.4 RAINFALL

Rainfall is one among the most important and the easiest to correctly quantify using rain gauges. Therefore, simpler and cost- effective means of an early warning system based on rainfall measurements and rainfall thresholds can be utilized to future forecast of landslide occurrences (Keefer et al., 1987; Aleotti, 2004). Once the threshold values of rainfall at which landslides are initiated in a particular area are known, the same can be used as a foundation for issuing early warnings, if the quantity of rainfall in that particular area can be predicted (NDMG 2009). If the predicted rainfall intensity exceeds the rainfall threshold, then warning message which can be sent to the regional administration, local community and rescue operation team. Thus, accurate and timely rainfall forecasting is very essential. The map in figure 4.9 shows that the most of the areas of south, east and north-eastern parts of the Nilgiris falls under low rainfall. The western and central areas receive moderate rainfall. Highest rainfall can be seen most in southern and few parts in the west of the Nilgiris.

Figure 1.5
Rainfall Map



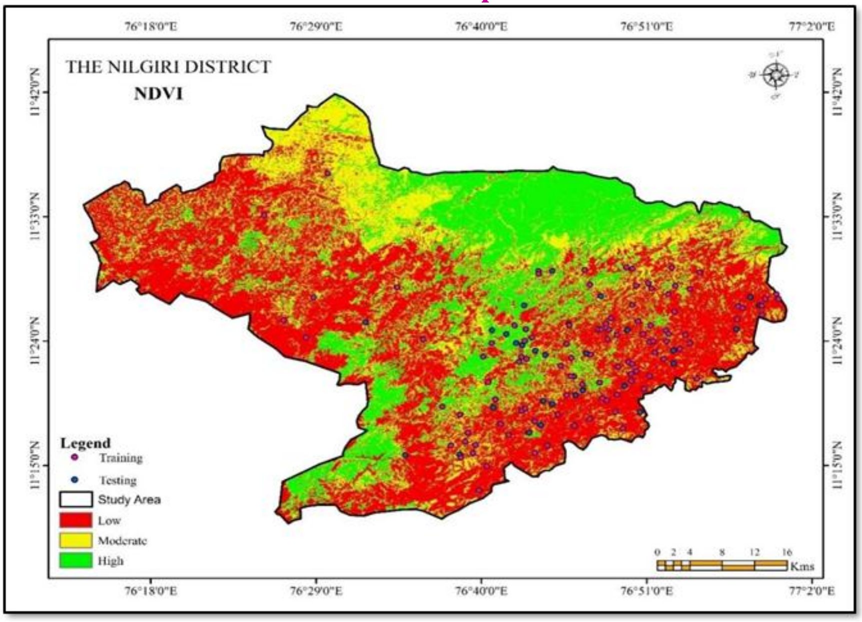
(Source: State Surface and Ground Water Board, Taramani)

The graph in figure 4.8 represents area wise the quantity of rainfall gets in Nilgiris district. Around 1094.41 sq. km area, which is 42.88% of the study area receives low rainfall. 1061.68 sq. km area which is 41.59% of the entire district receives moderate rainfall. Area with high rainfall received is 396.41 sq. km which is 15.53% of the Nilgiris district.

5.3 NDVI (NORMALIZED DIFFERENCE VEGETATION INDEX)

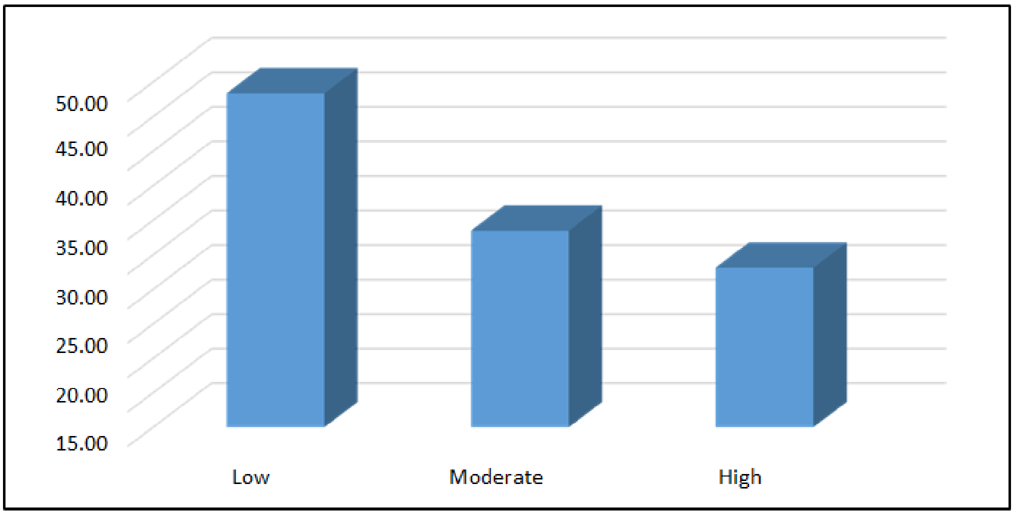
NDVI is the significant parameter for the prediction of landslide (Lee & Talib, 2005) (Pradhan & Lee, 2009). Less in vegetation becomes the promoting factor for landslide happening in mountainous area (Dahigamuwa et al., 2016). The high vegetation decreases the slope erodibility of the soil (Gomez & Kavzoglu, 2005) (Weerasinghe et al., 2011). Soil erosion is difficult to come by in a place with dense vegetation, terrain erosion is sluggish, and slope damage is little. The higher NDVI shows the higher vegetation growth. In figure 4.11 the following prepared map the north and south-western parts of Nilgiris district is found with high NDVI and also moderate NDVI can be seen in extreme northern region. Low NDVI can be seen in the east, west and southern portion of Nilgiris. The graph in figure 4.12 shows the area of NDVI coving area in percentage. Area covered with low NDVI is 1234.64 sq km, which covers 48.37% of the Niligir district. Moderate area is around 727.37 sq km and it is covering 28.50% of the study area. High NDVI region is about 590.50 sq km and it covers 23.13 of the whole district.

Figure 1.6
NDVI Map



(Source: USGS, 2019)

Figure 1.7
Spatial Distribution of NDVI



(Source: USGS, 2019)

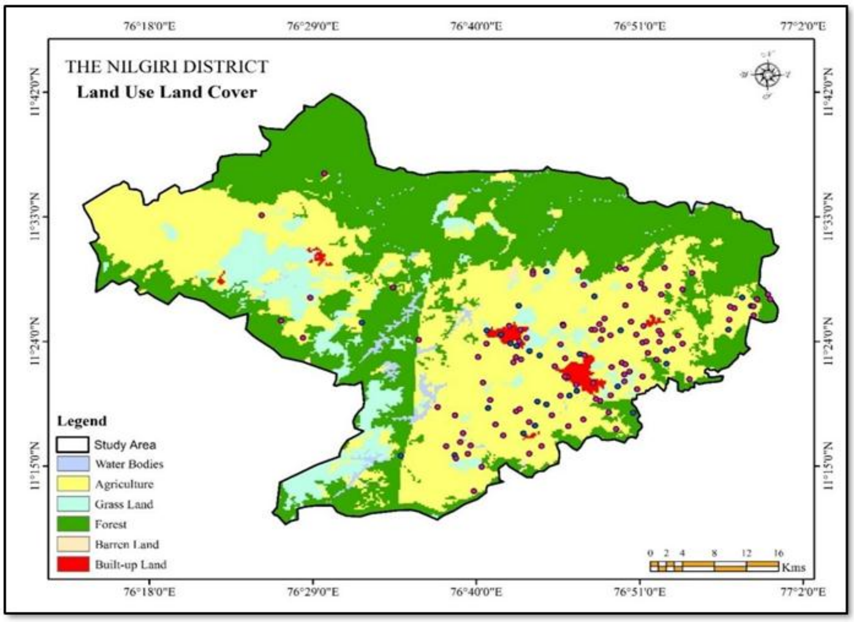
5.3.1 Land Use Land Cover

Land use is a significant factor that affects the landslides in the area under study. Generally, land use/land cover has effect on strength of slope materials against sliding and control of water content of slope. In addition, plant roots reinforce the slope and normally are considered as reinforcements. Land cover absorbs the water of soil and decreases the potential of landslide. In this study, land use/ land cover map is divided into 6 categories. According to fig: 4.15, water bodies are found in central and southwestern regions. Agricultural lands have covered the largest part of west, also spread all over the central, eastern and southern regions. Grassland is mostly found in west and south-western parts of

Nilgiris. The north, north-eastern regions and some parts in west and south-western regions are occupied with forest cover area. Barren land can be seen on one part of north and central region, also in the bottom of southern part. Built-up land is spread over the central, east, south-eastern regions. A small build-up region is also present in western part of the Nilgiris district.

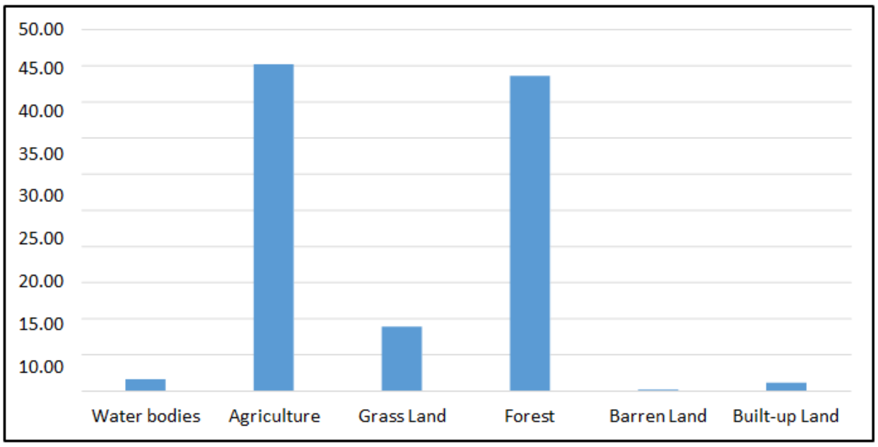
The graph in fig: 4.16 shows the percentage of different ctategories of LULC. As we can see 1.57% of the rigion has water bodies which covers 40.02 sq km area. Agricultural land is spread over 1148.48 sq km area and it covers 44.99% of the entire district. Grass land has 224.87 sq km area and it is covering 8.81%of the district. Forest cover area is 1107.12 sq km and it shares 43.37%of the region. Barren land in Nilgiris has 3.97 sq km area and it covers 0.16% of the distict. Bulitup land coves 28.04 sq km and it covers 1.10% of the entire region.

Figure 1.8
Land Use Land Cover Map



(Source: USGS, SRTM data, 2019)

Figure 1.9
Areal Distribution of Land Use Land Cover



(Source: USGS, SRTM data, 2019)

5.3.2 Lineament Density

The lineament is a linear feature of the terrain which includes faults, fractures, ridges, major discontinuities etc. (Sarkar, et al., 1995). The existence of lineaments may also greatly influence the stability of rock masses (Andreas and Allan, 2007). Lineament has been used as a important factor (Anbalagan and Singh, 1996; Nagarajan et al., 2000; Saha et al., 2002) for landslide vulnerability studies. Most drainage pattern follows major lineament trends (Süzen and Toprack, 1998; Ramli et al., 2010) and this is true in the case of a soil covered terrain like Nilgiris, wherein valleys with straight alignment define lineaments. In entire study area lineament density is low except the central, few parts of north, and southwest areas have moderate and high lineament density. The percentage of low, moderate and high lineament density of the Nilgiris district. The area coved by low lineament density is1684.85 sq. km and it occupies 66.01% of the entire district. Moderate lineament density has 508.90 sq. km and it covers 19.94% of the study area. The high lineament density occupies the area of 358.74 sq. km and 14.05% covering the entire district.

5.3.3 Taluk Wise Area Distribution of Landslide Prone Zone Based on Best Model

The table 4.10 shows taluk wise area distribution of landslide prone zones in Nilgiris district. Coonoor, Kotagiri, Udhagamandalam, Kundah, Gudalur and Panthalur are six taluks of the Nilgiris district. The category of landslide has been distributed into low, moderate and high categories.

Table 1.1
Taluk wise percentage share of total area

Taluk	Category	Area (sq km)	Percentage	Total %
Coonoor	Low	4.32	2.00	0.17
	Moderate	48.84	22.57	1.91
	High	163.29	75.44	6.40
Gudalur	Low	269.69	58.31	10.57
	Moderate	185.92	40.20	7.28
	High	6.93	1.50	0.27
Udhagamandalam	Low	60.13	6.62	2.36
	Moderate	492.78	54.29	19.31
	High	354.76	39.08	13.90
Kotagiri	Low	33.43	8.02	1.31
	Moderate	9.81	2.35	0.38
	High	373.37	89.62	14.63
Kundah	Low	219.68	76.77	8.61
	Moderate	66.45	23.23	2.60
	High	0.00	0.00	0.00
Panthalur	Low	218.42	83.01	8.56
	Moderate	40.69	15.46	1.59
	High	4.00	1.52	0.16

The Conoor taluk has area 4.32 sq km of low landslide prone zone with the percentage of 2.00 % covered in entire taluk and total 0.17% of entire Nilgiris district. Around 48.84 area comes under moderate zone which is the 22.57% of Conoor taluk and 1.91% area of Nilgiris district. The area falls under high landslide zones are 163.29 sq km, which covers 75.44% of the entire taluk and 6.40% part of district region. For Gudalur taluk the area covered with low landslide zone is 269.69 sq km, covering around 58.31% of Gudalur and 10.57% of area of Nilgiris district. The area covered with moderate landslide zone is 185.92 sq km, covering around 54.29% of Gudalur and 19.31% of are of Nilgiris district. The area covered with high landslide prone zones are 6.93sq km and it covers 1.50% area of entire taluk, with 0.27% of entire district. The next is Udhagamandalam and it has 60.13 sq km area comes under low landslide zone and it covers 58.31% area of entire taluk, with 2.36% of entire district. Around 492.78 sq km area comes under moderate landslide zone and it covers 54.29% area of entire taluk, with 19.31% of entire district. About 354.76 sq km area comes under high landslide zone and it covers 39.08% area of entire taluk, with 13.90% of entire district.

In Kotagiri area with low landslide zone is about 33.43 sq km which covers 8.02% of entire taluk and 1.31% of Nilgiris district. Here 9.81 sq km area comes under moderate landslide zone and it covers 2.35% area of entire taluk, with 0.38% of entire district. Around 373.37 sq km area comes under high landslide zone and it covers 89.62% area of entire taluk, with 14.63% of entire district.

The Kundah area covered with low landslide zone is 219.68 sq km and it cover 76.77% of entire taluk area with 8.61% of Nilgiris district. The area of 66.45 sq km is covered with moderate landslide zone with percentage sharing of entire taluk is 23.23% and total area of 2.60% of Nilgiris district. Kundah is not susceptible for high landslide. So, this taluk not focused much for primary data collection.In Panthalur about 218.42 sq km area comes under low landslide zone and it covers 83.01% of the entire taluk with 8.56% of Nilgiris district. Around 40.69 sq km area comes under moderate landslide zone and it covers 215.46% area of entire taluk, with 1.59% of entire district. Nearly, 4.00 sq km area comes under high landslide zone and it covers 1.52% area of entire taluk, with 0.16% of entire district.

Table: 1.2
Taluk Wise Distribution of Tribal Population

Taluk	Total Population	Tribal Population
Coonoor	157744	2354
Gudalur	104768	6616
Udhagamandalam	191960	6113
Kotagiri	108684	6312
Kundah	46307	521
Panthalur	125931	10897
Total	735394	32813

Kotagiri taluk has total population of 108684 and it has 6312 tribal population. Since 89.62% area of Kotagiri comes under high landslide prone zones, so this taluk was highly focused for collecting primary data.The Conoor taluk has total population of 157744 and the tribal population living in this district is 2354 and tribal people living in this region are second most vulnerable group. The total population of Udhagamandalam taluk is 191960. The tribal population lives here are 6113, so the vulnerability of tribal population is in third postilion. The next taluk Gudalur has total population of 104768 and total tribal population is 6616. The total population of Panthalur is 125931 and the tribal population is 10897. The tribal group living in Panthalur very rarely vulnerable. Kundah has the total population of 46307 and only 521 are tribal population. Since Kundah taluk doesn’t has high landslide zone so the tribal population has been considered are not vulnerable to landslides.

5.4 CONCLUSION

Landslide maps are useful for determining landslide susceptibility and risks, as well as investigating the development of landforms. Landslide inventory maps are effective and intelligible products for experts and non-experts, including decision- makers, planners, civil defence managers, and concerned citizens. This chapter deals with landslide prediction zones of entire Nilgiris district.

The classification of landslide hazards is an important step in the landslide management process. Several preparation and triggering variables impact landslides, and they differ substantially from area to region. For this study ten most influencing factors have been selected. In order to prepare maps for areas susceptible to landslide four models have been selected they are AHP Frequency ratio, Logistic regression and Shannon's Entropy.

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