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Study of Basic Causes and Effects in the Hilly Terrains of Nilgiris Using Remote Sensing and Geographical Information System

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ABSTRACT: Landslides are one of the most common natural disasters in hilly regions. The landslides were more in the Burliyar-Coonor-Ketti sector as the region received heavy rainfall. Natural slopes are disturbed due to cutting of roads for construction purposes, prevention of natural drainage and the changing land use pattern are the factors contributing to landslides. Most of the times it is triggered by high intense down pour. Economic damage and fatalities are also caused by widespread shallow and deep seated failures, triggered by intense or prolonged rainfall, by snowmelt or by earthquakes. Therefore there arises a need to predict the natural disasters in advance and mitigate them. This makes us to rely on the technical capabilities which has increased dramatically like Remote Sensing and Geographical Information System (RS & GIS). The growing population and expansion of settlements over these hazardous areas increased the impact of natural disasters in most of these areas. The aim of such study is to use a "working methodology" in which geoenvironmental parameters are analyzed for the basic causes and effects of the landslides using remotely sensed data products and geographic information system (GIS).

KEYWORDS: Landslide, rainfall, drainage, fatalities, natural disaster, hilly terrains, remote sensing and geographical information system

I. INTRODUCTION

A landslide is a downslope movement of rock or soil, or both, occurring on the surface of rupture—either curved (rotational slide) or planar (translational slide) rupture—in which much of the material often moves as a coherent or semicoherent mass with little internal deformation. Professionals like Engineers and Geologists define landslides in a unique and different way. Landslide phenomenon is associated with many disciplines it is associated with. Therefore, landslide can be described as the downslope movement of soil, rock and organic materials under the effects of gravity and also the landform that results from such movements. The term landslides can otherwise be used interchangeably with mass movements, slope failure and so on. Landslide activities are closely associated with the tectonically active regions, and are the most common natural hazards which lead to damage in the road sector and residential areas in the hilly terrains (1).

II. MATERIALS AND METHODS

STUDY AREA

The study area is Nilgiris district, which is located in Tamilnadu state and lies between the latitudes 11° 10' and 11° 43'N and longitudes 76° 15' and 77° 00'E and it covers 2541 km². The study area falls under the Survey of India

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toposheets No: 58 A/6, 58 A/7, 58 A/8, 58 A/10, 58 A/11, 58 A/12, 58 A/14 and 58 A/15. The Nilgiris is situated at an elevation of 2636 meters above Mean Sea Level (MSL). It is surrounded by the states Karnataka in the north, Kerala in the west and south and the districts Erode and Coimbatore of Tamilnadu in the north east respectively. The geographical area consists of six taluks namely Udhagamandalam, Coonoor, Kotagiri, Gudalur, Kundah and Pandalur. The upper plateau at an altitude of 6,500 feet consists of three Taluks namely Udhagamandalam, Coonoor and Kotagiri while Gudalur Taluk is the oldest plateau at an altitude of 3,000 feet. There are four Panchayat Unions in this District. The four Municipalities are Udhagamandalam, Coonoor, Gudalur and Nelliylam.

The topography of Nilgiris district is rolling and steep. Tea, cabbage, potato, pepper, carrot, coffee and spices are important agricultural products of the district. The Nagapattinam – gudalur National Highway (NH 209) passes through the district. The natural boundary of the plateau along much of its Southern side is the Bhavani river and the Northern frontiers is bounded by Moyar river. These two rivers i.e Bhavani and Moyar are the main river streams that drain the Nilgiri hills, Pykara river, Sigur river, Kavithole halla, Kedirayar halla, Kalavahalla, Madukadu halla and other streamlets originating from northern parts of the Nilgiri hills flow northward to join Moyar river. Kundah river, Katteri river, Coonoor river, Neeralipallam and other streams flow in the South Easterly and Easterly directions to join the Bhavani river.

The Nilgiris district usually receives rainfall from both during south west (June, July) and north east (October, November) monsoons. The daily rainfall data of the Nilgiris district from 29 rain gauge stations for 29 years were collected from the Indian Meteorological Department, Chennai. The soil texture of Nilgiris district includes clay, clayloam, loam, loamsand, sandyclay, sandyclayloam and sandy loam. . Digitized Soil map (1:50,000 scale) of the study areas was obtained from the Department of Remote Sensing and GIS, TNAU, Coimbatore .

The Slope Map was prepared from the aster Digital Elevation Model (DEM). From the slope map, slope percentage has been calculated. Slope is an important factor in the analysis of landslide. As the slope increases, the probability of the occurrences of landslide increases because as the slope angle increases the shear stress of the soil increases (2). The topography of the watershed is undulating with varying slope from 1 to 74%. The drainage network map of the study area has been delineated using the DEM image in the GIS environment. The stream orders I, II, III and IV were delineated from the drainage network in the ArcGIS environment. . Drainage density Map of the study area has been prepared and found to be in the range of very low, low, medium, high and very high for the study purpose. The places where the drainage density is high, water washes out the cementing material from soil and rock masses. Water pressure intension cracks not only push the slope forward but it also generates pore water pressure along joint or bedding planes. Thus the plane of sliding acts as a natural channel for the flow of water (3)

The lithology details were obtained from the Department of Remote Sensing and GIS, TNAU, Coimbatore. The lithology of the study area includes Alkali rocks, Charnockite group, Migmatite complexes, Peninsular Gneiss and Sathyamangalam group. The geomorphology details were obtained from the Department of Remote Sensing and GIS, TNAU, Coimbatore. The geomorphology of the study area includes Denudated hill, Structural hill or hill top weathered, Piedmont slope, Structural valley and Valley fill. The erosional surfaces in Dodabetta, Ootacamund, Coonoor and Moyar are recorded in the district. All these erosional surfaces are capped by residual laterite(4). The Lithology in the study area is charnokite group of bedrocks, covered by the ubiquitous red laterite or lateritic soil (5).

Aspect is measured in degrees from North to again North. . The aspect map was prepared from the DEM image and it indicates that the East, Southeast, South and Southwest and parts of West were highly susceptible to landslides due to direct sunlight and rainfall. Ranking is assigned to directions and formed as a thematic layer.

The Land use and land cover map was prepared using the downloaded Satellite Image LandSat 8 of with the date of acquisition on May 2014 with path 144 and row 52. The composite image was used to prepare the Land use/land cover of the study area in the ArcGIS environment. The supervised classification was done using the visual interpretation and expert consultation for identifying the tone and hue of the image. The land use/land cover is characterized by a mixture of Dense forest,

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Vol. 6, Issue 10, October 2017

Mixed plantations, Tea plantations, Agro horticultural plantations, Barren land, Agricultural Land and water bodies. The land use and land cover play important role in instability of slope. Woody type helps in stability of slopes. Vegetation provides both hydrological and mechanical effects that generally are beneficial to the stability of slopes. These include impact of climate, geologic and topographic conditions on the distribution of soils, vegetation and occurrence of water (6). Lithology, Lineament density, Geomorphology, Slope and Land use/ Land cover which only dominantly assign the landslide vulnerability grades to the mountain regions (7).

Remote sensing (RS) data and GIS play a rapidly increasing role in the field of land and water resources development. One of the greatest advantages of using RS data for natural resource management is its ability to generate information in spatial and temporal domain, which is very crucial for successful model analysis, prediction and validation. In the present study the ArcGIS 9.2 was used for integration, manipulation and analysis of data for the assessment of Landslide Hazard zonation (LHZ). All the thematic maps such as base map, drainage map, slope map, aspect, lithology, geomorphology map, soil map, Land use/ land cover, drain density map, rainfall map and lineament density map of the study area were prepared in the ArcGIS 9.2 environment.

The rainfall analysis for all the available rainfall data was carried out to understand the variations in the (total/mean) rainfall. The rainfall data were interpolated using Krigging method to predict the values at unmeasured locations from the surrounding measured locations. A continuous surface or maps of the rainfall phenomenon were created for predictions using the spatial arrangement of the measured values in the nearby locations. The coefficient of variability of the annual rainfall and seasonal rainfall were calculated. The precipitation ratio can be defined as the difference between the maximum and minimum rainfall of over the series of years expressed in the terms of mean. This ratio may give the stability of the rainfall with special relationship. Higher the ratio is higher in abnormality in rainfall and vice versa (8). Markov Chain model has been used with a threshold of 20 mm limit for estimating the weekly rainfall probability. Reddy applied Markov chain model in Combolcha station, Ethiopia by choosing 10, 20, 40 and 80 mm/week as threshold limits(9).

The rainfall zones of the watershed can be summarized as

1. Very low rainfall zone (below 700 mm): No lowest rainfall zone stations are observed.
2. Low rainfall zone (700 – 1000 mm): Emerald and Kunshola falls under this category.
3. Moderate rainfall zone (1000 – 1700 mm): Adarly, Governor shola, Naduvattam, Avalanche falls under this category.
4. High rainfall zone (1700 – 2500 mm): Runnymedu, Kotagiri, Ooty, SCR Ooty, Glenmargan and Kundah receives maximum rainfall fluctuating from more than 1700 mm.
5. Very high rainfall (>2500 mm) - Coonoor, Coonoor Railyway, Hill groove and Kethi receives highest rainfall of more than 2500 mm with highest recorded in Coonoor and lowest in Hill groove.

All the maps prepared were in the vector format and for analyzing purposes all the maps were rasterized which is the process of converting an images of lines and polygons from vector representation to a grid format. Overlaying of all the rasterized layers were done to analyze the various spatial data included in the area. Ranking is done according to the required criteria on priority basis. Highest ranking was given to criteria which were most prone to land hazards and less ranking was given to criteria which were less prone to landslide hazards. For this purpose, several experts have been consulted and literatures were reviewed.

III. RESULTS AND DISCUSSION

The main causes as analyzed for the occurrences of landslides in the Nilgiris region were the heavy down pour of the monsoon rain in hill slopes and widening of roads in hills as a measure of developmental activities by the government department. The anthropogenic causes are the vertical face cutting of the hill slopes, lack of proper

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sewerage system in the habitations located on the hill slopes, unauthorized increase in built up areas for residential and commercial purposes constructed in the unstable slopes. Excess percolation of water into the earth due to the heavy down pour and improper sewerage system were the factors contributing to landslips. Anthropogenic causes and deforestation results in loosening the stability of the soil and blocking of the channels which results in diversion of floods, excavation at the toe of the slope and dumping of loose waste adds risk of the landslides. Around the 80 landslides investigated within the Nilgiris district, 41 occurred in the Burliyar, Coonoor and Ketti sector where heavy down pour triggered the landslides.

The location of the pre historical landslides has been included as a thematic layer. The types of landslides during 2009 were fresh soil slips, rock or debris fall, rock slides, massive boulder thrashes and debris slide etc. The debris flow was reported to extend from 1/9th to 3/9th hairpin bend.

Weighted overlay method is adopted to overlay several raster layers based on a common measurement scale and by providing weights according to its importance and obtaining the results. Ranks and weights of causative factors were assigned in order to generate a landslide hazard zonation map. The relevant factor for landslide hazards zonation mapping shall include slope, relative height, lineament density, drainage density and drainage pattern, soil type, geomorphology, Lithology, land use / land cover and rainfall. The stability of an area depends on the combined effects of all the above indicated factors. The maximum LHZ weights for different categories were determined on the basis of their estimated significance in causing instability and resulting in landslides. The important factors responsible for the landslides were assigned ranks on a 1 to 5 scale in order of importance. Weights were assigned to the classes of the factors on a 1 to 100 ordinal scales where higher weight indicates a greater susceptibility to landslide occurrence(10).

Based on the themes and its impact different hazard zones were delineated and classified into 5 classes namely Very Low, Low, Moderate, High and Very High Hazard zones. The results were validated using the percentage of previous number of records of landslides in the resulting zonation map.

IV. CONCLUSION

The intensity and frequency of landslides have increased due to the climatic conditions, topography and geology of the area in Nilgiris. The anthropogenic factors like deforestation, roads construction and expansion, improper water intensive agricultural practices, building residential houses in steep slopes without any environmental impact assessments also adds to the increase in the intensity and frequency. The vulnerability of the fragile and unstable geology of the Nilgiris also has increased the risk of landslides due to unscientific developmental activities. The consequences of landslides include the loss of living beings, damages to roads, houses, properties, agricultural lands, transport and communications. The basic causes and effects of landslides in the Nilgiris has been analyzed as the heavy down pour of the monsoon rain in the hill slopes. The anthropogenic causes of vertical cutting of slopes for developmental purposes and lack of proper sewerage system in the habitation and unauthorized buildings in the unstable slope lead to landslides during monsoon season. Improper land use such as agriculture and other plantations have a higher susceptibility to landslides in the study area.

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