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ZONING AND MAPPING OF LANDSLIDE HAZARD IN THE NILGIRIS DISTRICT, TAMIL NADU, INDIA

R. Aneesah[114] & V.M. Suresh[115], S.V. Varshini[116] & K. Nijamir[117]

Correspondence: aneesah0786@gmail.com

ABSTRACT

Landslide is the frequent disastrous events in the Nilgiris District. It shows a historical record in the study area. The objective of this present study is to prepare a landslide hazard zonation map. The present study has been carried out by using secondary sources of data. Total of 33 landslides has been recognized through Landsat-8 satellite imagery. In this study, five parameters have been taken such as land-use/ land cover, rainfall, slope, aspect and geology. The hazard zonation map has been done with the technique of Weighted Overlay Analysis by using GIS software ARC GIS 10.4. The results of this study reveal that most of the landslide has occurred in the east and center part of Nilgiris district which are highly prone to landslides. These regions are in very high and high zones. The northern most part of the Nilgiris is in the low zone due to dense forest covered. There are only 0.21 percentage of area is in under very high zone, 1.82 percentage is under the high zone, 41.72 percentage is under the moderate zone,50.38 percentage is under the low zone and 5.91 percentage is under very low zone out of the total study area. Therefore, the results of this study also reveal that the final map of hazard zonation can be useful for mitigating the hazard and is very helpful to planners and engineers for determining the safe and suitable locations to continue the developmental works.

Keywords: landslide, hazard zonation, weighted overlay analysis, GIS, Nilgiris

INTRODUCTION

Landslide hazard causes in loss of lives and extensive property damages, and these became a major problem of maximum countries. Penang Island in Malaysia experiences frequent rainfall and this region is susceptible to landslides. Tropical rainfall along with uncontrolled urbanization and deforestation play an effective role to aggravate slope destabilization in this island (S. Lee and Pradhan, 2006). In order to forecast and specify the region where future land failure is likely to happen, it is necessary to mapping the landslide prone areas (Althuwaynee, Pradhan, and Lee, 2012). Reliable and accurate landslide susceptibility map can be helpful for land planners, decision makers, and for risk assessment. Over the last few decades, Geographic Information System (GIS) has become a compulsory tool in landslide hazard and risk assessment, thus many landslide susceptibility maps have been produced using different GISbased methods including the analytical hierarchy process (AHP), frequency ratio, bivariate, multivariate, Logistics Regression, Fuzzy logic, and Artificial Neural Network (Matori, Basith, and Harahap, 2011). Although, all techniques have advantages, incomplete knowledge applied through qualitative methods makes the expert

[114] CNHDS, University of Madras, Chennai 600025.
[115] CNHDS, University of Madras, Chennai 600025.
[116] Sir Rajalaximi Engineering College, Chennai, India.
[117] Department of Geography, South Eastern University of Sri Lanka.

decisions inaccurate or wrong, and imprecise or inaccurate data have the similar impact in the case of using quantitative approaches (Vahidnia, Alesheikh, Alimohammadi, and Hosseinali, 2010). Therefore, the results from the different mixture of qualitative and quantitative techniques, known as semi-quantitative approaches, which merge ranking and weighting, may be more credible (Ayalew and Yamagishi, 2005). The Analytic Hierarchy Process (AHP) (Saaty, 1980), and analytic network process (ANP) (Saaty, 1999), Weighted Linear Combination (WLC) (Ayalew, Yamagishi, and Ugawa, 2004), and Fuzzy Logic theory (Zadeh, 1965), are the examples of semi-quantitative techniques.

In this study the Weighted Overlay Analysis has been applied for preparing the landslide hazards zonation mapping. This is one of the common as well as popular methods for hazards zonation mapping through ArcGIS software.

Landslides are the common disastrous events in the Nilgiris District, it shows a historical record in the study area. The main cause of landslide events in the study area is heavy intense rainfall which is occurred during October and December. The study area Nilgiris District has a steep and rugged hilly topography with poor geological formations and is situated at an altitude of 1,370m above Mean Sea Level (MSL). Lithologically major part of the area is covered with charnockite rock which covers more than 60 percent of the study area, and this vulnerable rock has increased the landslide which is affecting the life and property of the residents. Being a very attractive tourist spot, the district has been growing very fast, especially since last decade. Many multi-storied buildings have been constructed on the weak, fragile and seismically active hill slopes to accommodate the influx of tourists. The heavy loadings of slopes by such buildings have made the slopes vulnerable to landslides resulting in great loss of human lives and properties. Communication network is also disrupted due to it. Landslides pose a great threat during rainy season in most of the localities and cause hardship and related hazard problems.

OBJECTIVE

The objective of this present study is to prepare a landslide hazard zonation map for Niligiri district, Tamil Nadu, India.

STUDY AREA

The hilly district Nilgiris is situated in the northwestern part of the Tamil Nadu state which is covered an area of 2,500 sq. km. The area lies between 11°12 N to 11°37 N latitude and 76° 30 E to 76° 55 E longitudes. The northern part of the district is bordered by the state of Karnataka, western and southern parts by the state of Kerala and in the east by the districts Erode and Coimbatore respectively. According to 2011 Census the total population of the study area is 735394.Lithologically the area is covered by Charncokite and pyroxene granulite. The deeply weathered rocks are occurred in the entire region and soil thickness is found to be upto 40m. Geomorphologically this area is situated at an altitude of 1,370m above Mean Sea Level. Topographically this area is a hilly region. The dendritic and radial pattern drainages are found at places with prominent rapids and waterfalls. The maximum

and minimum summer temperature is 25°C and 10 °C respectively. In winter season this region has a maximum temperature of 20°C and a minimum temperature of 0°C. This region receives heavy rainfall from both South-west and North-east monsoon winds. The headquarters of the district is Ooty, which is one of the prominent tourist stations in South India.

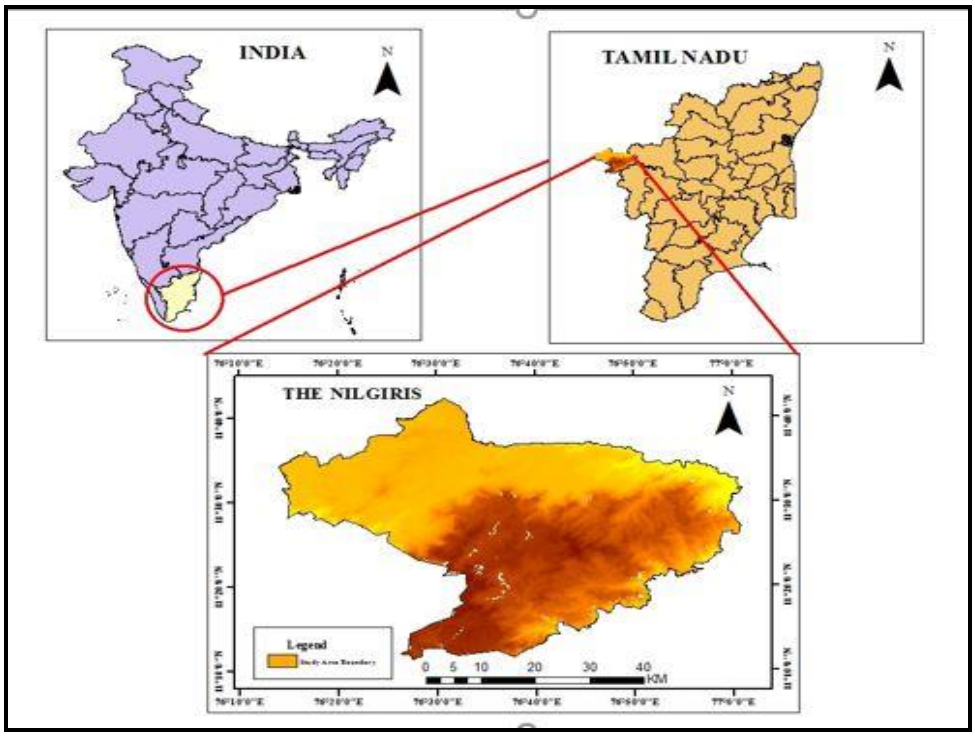

Figure 1: Study Area Map

3DATABASE AND METHODOLOGY

The present study has been carried out by using secondary sources of data. Total 33 landslides have been recognized through Landsat-8 satellite imagery. Landsat-8 image of January, 2016 has been downloaded from the USGS Earth-explorer. Land-use map has been prepared from Landsat image. Monthly rainfall data of two decades from 1996 to 2016 has been taken from the India Meteorological Department (IMD). Geology map of 1:50,000 has been taken from the Geological Survey of India (GSI). Slope and Aspect map has been prepared from the SRTM DEM data, which has been downloaded from the USGS Earth-explorer.

Table 1. Data used in the present study area

Data type	Source	Data derive
SRTM DEM	USGS Earth-explorer	Slope and Aspect map
Landsat-8	USGS Earth-explorer	Landslide inventory map,

		LU/LC map
Meteorological data	India Meteorological Department (IMD)	Rainfall Map
Geology	Geological Survey of India (GSI)	Rock type map

The Weighted Overlay Analysis in one type of semi-quantitative technique which can measure the theory and also this technique has plays an important role in decision management in analysis of site suitability, landslide management, planning of region etc. This technique is related to GIS environment. Overlay analysis is related to AHP technique and it is the function of GIS software. In this present study the hazard zonation map has been done with the technique of Weighted Overlay Analysis(WOA) and rank value of each factor have been done to prepared this hazard zonation map of the study area. Before applying the WOA method, all the thematic maps have been integrated by using GIS software ArcGIS 10.4. The base map has been prepared on the basis of Google earth map and satellite images of the study area. For this study, seven factors, such as geology, slope, aspect, soil, rainfall, land-use, roads and landslide location of the study area have been used to prepare the Landslide Hazard Zonation Map. With the help of this technique the zonation such as very high to very low has been done.

RESULTS AND DISCUSSION

The Nilgiris district in the Western Ghats has a long history of disastrous landslide events. In the recent times casualties and damage due to landslides have increased in the Nilgiri Hills. The district receives heavy rainfall during North East Monsoon, so generally October to December is the season for landslide in this region. The notable landslides have been recorded from the year 1865 to 2009. The present study gives an over view of the various causal factors involved in triggering of landslides in Nilgiris. Figure 2 explains the location of landslides in Nilgiri district.

Geology

There are various types of rock in Nilgiri District. Charnockite is one of the major types of rock which cover more than 60 percentage of the area. In this study, lithological map has been classified into five classes such as alkali rock in the east side, charnockite group which is found in the east and southern part of the region, migmatite complex in the west side, peninsular gneiss in the northern part of the district and satyamangalam group in the most western side of the study area (figure 3).

The figure 3 shows that all of the landslides occurred in the charnockite rock which is very prone to landslides. This rock is basically metamorphic rock and also a weathered rock due to high temperature.

Geomorphology

The study area is situating at an altitude of 1370 m above mean sea level. This area is surrounded by the plains and plateau region such as Coimbatore plain situated in the south-east, Bhavani plain in the north-east, in the northern side MoyarValley and in the north-east Gudalur Plateau. According to Geological Survey of India Dodabeta is the highest peak in Tamil Nadu state. Moyar is the major river in this region which flows in the northern portion of this district.

Rainfall

The study area Nilgiri District faces heavy intense rainfall two times in a year during South-West and North-East monsoon. Gudalur, Pandalaur and Kundah taluks, some parts of Udhagamandalam taluk of this district receive rainfall by the South-west monsoon and the whole Coonoor and Kotagiri taluks faces rainfall through North-east monsoon. In this district 16 rainfall stations are there and the average rainfall of this area is between 1500mm-3000mm.

In this present study, two decades of 1996 to 2016 rainfall has been taken to show the rainfall distribution map of the study area. Rainfall map has been classified into six classes such as 1000-1200 mm, 1200-1400mm, 1400-1600mm, 1600-2000mm, 2000-2400mm and 2400-2800mm. The figure 4 shows that maximum landslides occurred in between 1600-2000mm class and few are in between 2400-2800mm class in the study area.

Slope

Slope is an important factor in the analysis of landslide. As the slope increases the probability of the occurrence of landslide increases because the shear stress of the soil increases. In this study slope map has been prepared from the SRTM DEM data with the help of spatial analyst tool in GIS platform. The slope map has been classified into five classes in degrees such as 0^0-8^0, 9^0-20^0, 21^0-40^0, 41^0-60^0 and >60^0. The figure 5 shows that maximum number of landslides occurred under 21^0-40^0, few are in 41^0-60^0 class. Hence it can be said that the slope has a major role behind landslide events.

Land use pattern

Changes in vegetation cover and cropping pattern often contribute to landslides (Glade, 2003). From various studies, it is learnt that land use pattern of thick afforestation area and deep root helps to stabilize the slopes. The areas with thick vegetation were less prone to sliding with reference to the area with mild or no vegetation. (Gokceoglu and Aksoy, 1996). In this study the land use/ land cover map has been classified into five classes such as arable land, settlement, forest, waterbody and scrub and grass with the help of GIS software 10.4 version. The figure 6 shows that, most of the landslides occurred in the agricultural land as well as near to settlements. Remaining landslides occurred in the scrub and grass lands and also near the waterbodies.

Landslide Hazard Zonation Map

Landslide hazard zonation mapping useful tool which works as a risk reducer in decreasing the risk of landslides. The Landslide hazard zonation mapping can be done by using many techniques. In this study, WOA method has been applied to prepare hazard zonation mapping in Nilgiris District, Tamil Nadu. Due to geology, geomorphology, climate and the heavy load of population make this region landslide prone zone. Total 33 landslides have been detected in this study area through satellite images. Most of the landslide has been occurred due to land use/ land cover changes, steep slope, slope direction, rock types and heavy rainfall.

Figure 7 shows the landslide hazard zonation map of the Nilgiris district. The five layers including geology, slope, slope direction, land use/ land cover changes and rainfall have been considered as the most important causative factors of landslide in the present study area. The results of this study reveal that the most of the landslide has been occurred in the east and center part of Nilgiri district which are highly prone to landslides. These regions are in Very high to high zones. The northern most part and the west side of the study area are in the very low zone due to densely forest covered.

From the figure it is clearly identified that the 2.03 percent area is under very high and high zone which are covered by the Charnockite rock formation, very prone to landside events. 56.29 percent areas are under low and very low landslide hazard zone which are fissile hornblende biotite gneiss rock type. Remaining 41.72 percent areas are under medium hazard prone zone which is also under the charnockite rock type. Most of the arable land has been noticed in this zone. Table 2 shows the percentage of area under landslide in the study area.

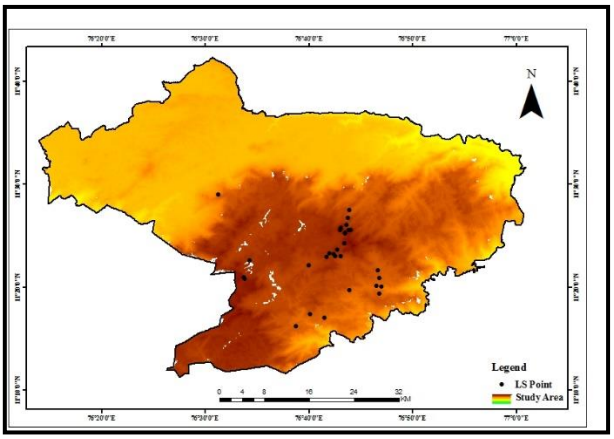

Figure 2: Landslide Location Map

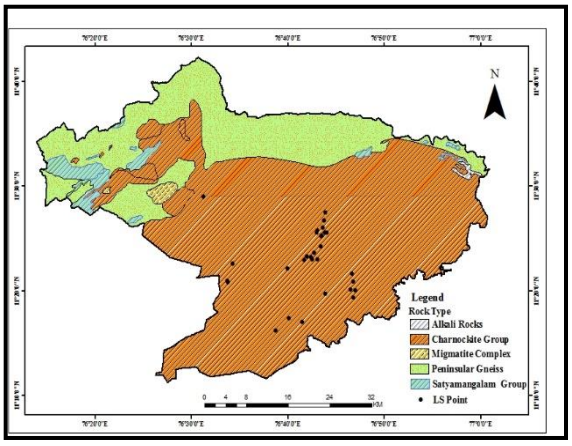

Figure 3: Lithology Map

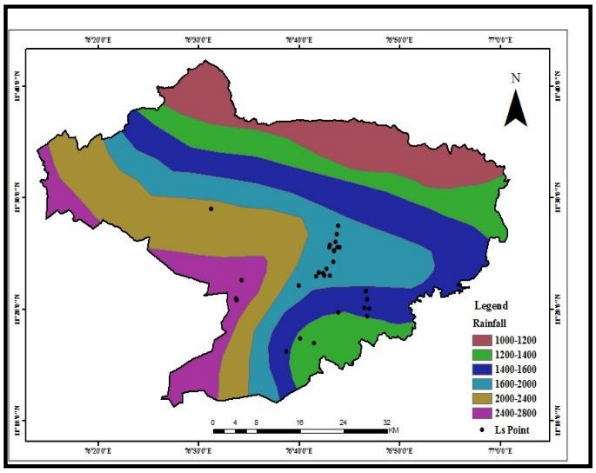

Figure 4: Rainfall Map

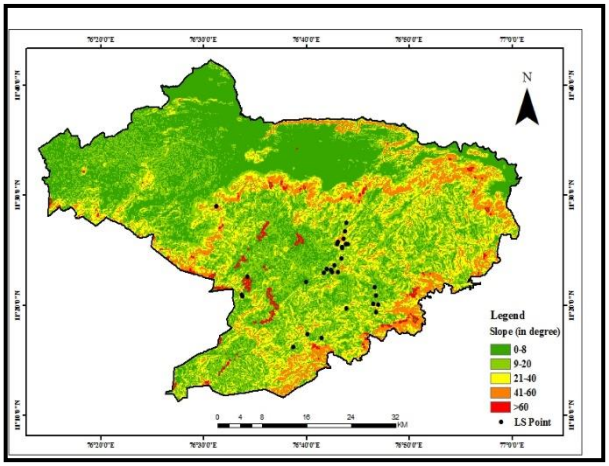

Figure 5: Slope Map

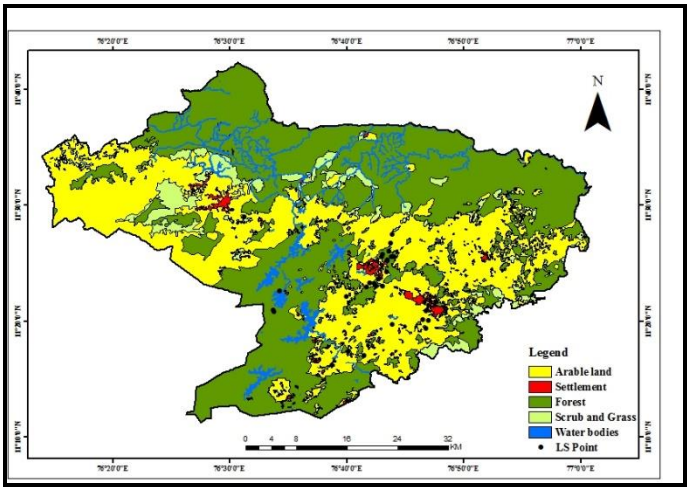

Figure 6: Land use/ Land cover Map

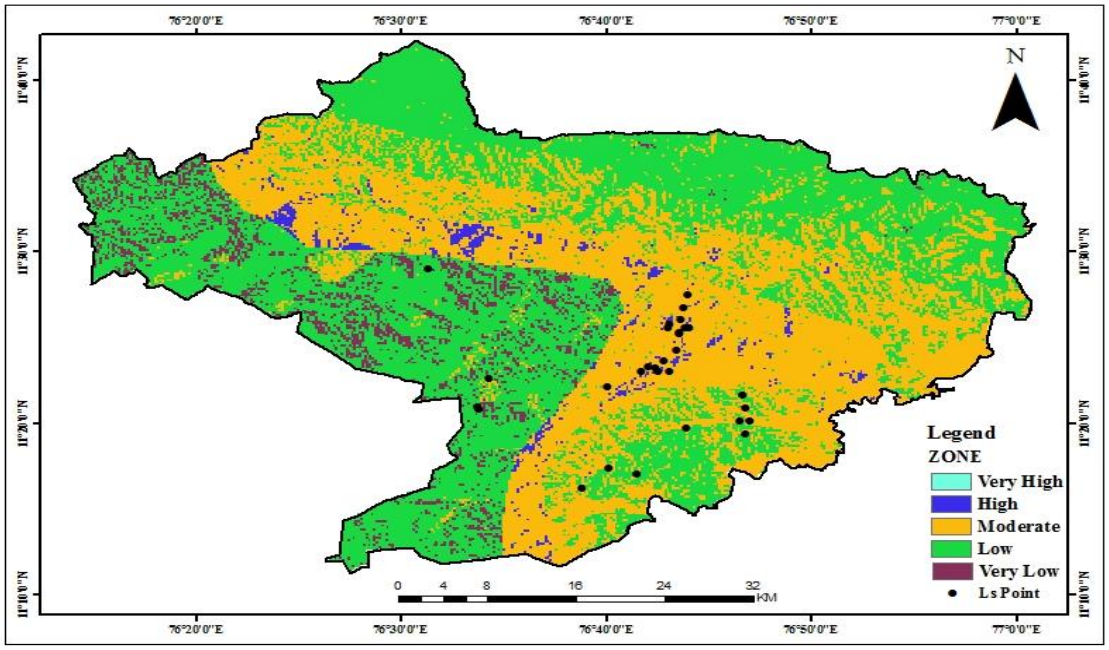

Figure 7: Landslide Hazard Zonation Map

Table 2: Shows the Hazard Zone with Percentage of Area and Landslides

Hazards Zone	Area (%)	LS(%)
Very high	**0.21**	**0**
High	1.82	12.12
Moderate	41.72	72.73
Low	50.38	15.15
Very low	5.91	0

CONCLUSION

From the above study it has been concluded that the results of this study can be more developed either with the help of other methods which is include direct or indirect impact on the landslide and which are not taken in this study or to improve those factors which were taken like lithology, slope, land use/ land cover and high resolution satellite data for accurately detecting the landslide area in this study to prepare the landslide hazard zonation map using WOA methods with the help of ArcGIS software. Therefore, the results of this study also reveals that the final map of hazard zonation can be useful for mitigating the hazard and is very helpful to planners and engineers for determining the safe and suitable locations to continue the developmental works. Another main issue is no clear early warning system is readily available for landslides, possibility of the occurrence of an event, the size

and in a location that would cause casualties, damage or disruption to an on hand standard of safety. In the hazard prone areas, no clear warning is nowhere designated in the vulnerable slopes. In this regard the local people can take initiation in help of Government officials to create awareness among the vulnerable community. This study can be suggested that if we want to reduce or prevent the risks and damages of landslide in the study area, it is recommended to the local people to do land use changes according to planning and also prevent the deforestation in the district.

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