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Demarcation of landslide vulnerable zones in and around Achanakal, South India using remote sensing and GIS techniques

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Present study attempted in Kattery watershed, Nilgiris District, Tamil Nadu, India where a major landslide occurred on 9th November 2009. Various thematic maps pertaining to landslide hazard studies were prepared from the toposheets and satellite imageries using Geographical Information System (GIS). Landslide hazard zonation map of Kattery watershed was prepared by assigning proper weights and ranks for various themes. The north eastern and southwestern part of Kattery watershed is more vulnerable to landslides and the southeastern part is less vulnerable.

[**Keywords:** Achanakal region; Kattery watershed; Landslide hazard zonation; Remote sensing and GIS]

Introduction

A landslide is a geological phenomenon due to the movement of a mass of rock debris, or earth down the slopes[1] and encompasses events such as ground movement, rock falls, and failures of slopes, topples, slides, spreads, and flows such as debris flows, mudflows or mudslides[2]. It often takes place in conjunction with earthquakes, floods and volcanic eruption. In the hilly terrain of India including the Himalayas, landslides have been a major and widely spread natural disaster that often strike life and property. Slope instability is a geo-dynamic process that naturally shapes up the geomorphology of the earth. However they are a major concern when those unstable slopes would have an effect on the safety of people and property[3].

Landslides in Western Ghats (region like Nilgiris) which occur frequently, often result in significant damage to property and agriculture. The trigger for the landslides was a period of heavy rainfall, and as there had been little effort to assess or predict the events, damage was extensive[4]. Kattery Watershed is in the Nilgiri hills of Western Ghats mountains system. It is situated at 6 km from Ooty on the Ooty-Coimbatore Road, Tamil Nadu, India. It falls between latitudes 76°41'0"E ~ 76°45'0"E and longitudes 11°19'0"N ~ 11°24'0"N. The watershed comes in the Survey of India toposheet 58 A/11 published on 1: 50,000 scale. The watershed has a maximum elevation of 2400 m above MSL and is characterised with steep slope, lateritic soils and fairly good drainage network. Forests, cultivation of potato and other vegetables on inwardly graded bench terraces was widely adopted earlier and thus problem of erosion and sedimentation down below were largely seen. However, about two decades before, with market fluctuations tea plantation has become popular.

Fig. 1 Base map of Kattery watershed

Most of the terraces were defaced to plant tea along the slope. Consequently, erosion got accelerated and silts flowing out silted up the Kattery Reservoir that caters to the needs of defence's cordite factory at Aravankadu. In 1984-85, the reservoir was desilted at a huge cost and thus this high priority watershed was taken up for treating again to arrest soil erosion, reduce sediment inflow to Kattery Reservoir and improve the livelihood of the watershed families. The base map of the watershed is illustrated in the Figure 1.

Landslide can cause extensive damage to life and property in hilly terrains during and after heavy rainfall[5]. Kattery watershed receives rainfall from both southwest and northeast monsoons. The southwest monsoon is more active contributing nearly 46% and the northeast monsoon is moderate, contributing nearly 38%. Average annual rainfall of this region is about 1850 mm. The climate of Nilgiri district is temperate and salubrious throughout the year. Mornings in general are more humid than the afternoons, with the humidity exceeding 90%. In the period of June to November the afternoon humidity exceeds 85% on an average. In the rest of the year the afternoons are low, the summer afternoons being the lowest. The day temperature in the district varies from 22.1°C in summer to 5.1°C in winter. The night temperature drops to 0°C in some times. The summer begins early in March, the highest temperature being reached in April and May. Weather cools down progressively from about the middle of June and by January; the mean daily maximum temperature drops to 5.1°C.

Materials and Methods

With the availability of data from remote sensing satellites, it has become possible to efficaciously collect and analyze synoptic spatial data, such as geology, structural features, land use / land cover, drainage, settlements etc. Geographical Information System (GIS) computational techniques offer numerous advantages in multi-geodata handling for integrated geo-environmental studies[6]. Several thematic maps were prepared from toposheets and satellite imageries to understand the important parameters like drainage, slope, geology, geomorphology, landuse etc. All the thematic maps were integrated using GIS and finally the landslide hazard zonation map of the watershed was prepared by assigning proper ranks and weightages. Field work was carried out in Kattery watershed to verify the thematic maps and also to collect soil samples for testing. Recent landslides and old landslide scars were investigated in the field. In the present study focus was given to the massive landslide occurred on 9th November 2009 at Achanakal region. It happened in the early morning due to sudden cloud burst and continuous heavy rainfall. Some remedial measures such as construction of retaining walls, plantation and construction of roads were being carried out during our field visits.

Results and Discussion

Drainage pattern observed in Kattery watershed is mainly dendritic in nature. The drainage is influenced mainly by the joint patterns and the foliation trends of the rocks. Some streams have straight courses. The stream courses follow the fracture patterns of the underlying rocks. Drainage map (Fig. 2) shows that the first order streams are high in the northwestern part of the watershed. It is understood that it is an elevated area and the erosion rate is more. There are two water bodies exist in the southeast part of the study area. Due to high erosion rate, siltation is more in these water bodies. Hence, the silt monitoring station is also located in this region. Prolonged rainfall will increase infiltration and create a saturated soil which reduces shear strength thus it leads to slope failure. Besides the presence of water in the soil or rock supplements the overall weight of the slope, which increases the shear forces causing the slope less stable[7].

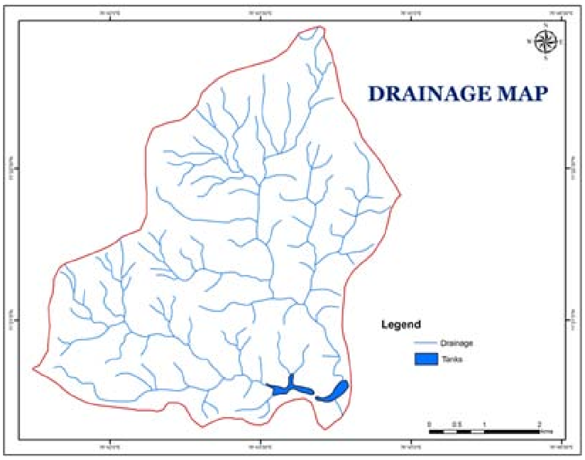

Fig. 2 Drainage map

Majority of landslides occur close to the streams within a distance of 100 m and some of the landslide occurs in 100 m to 150 m distance. Beyond 150 m there is not much chance for occurrence of landslides. Hence drainage buffer (Fig. 3) can be taken as basis for landslide hazard zonation mapping. This is because the erosion rate will be high near the streams. The drainage density is also an important factor as rain water percolates in areas with low drainage density. Moreover, the erosion action by streams also plays a role in increasing the slope instability. If the drainage density is high the water percolation will be less and erosion rate will be more. Further, high drainage density is encountered in steeper slopes.

Drainage density map of Kattery watershed (Fig. 4) was also prepared from satellite imageries using GIS. It shows that the drainage density is high in northwestern part and moderate to low in southeastern part. Steep terrain and high frequency of rainfall make landslide occurrence frequent on natural terrain[5]. Slope map of the watershed was prepared using GIS. Slope is classified into three categories viz., low, medium and very high (Fig. 5). It is found that majority of the area falls in the category of medium followed by very high and low. It is evident that high to very high slopes are restricted to landslides as such areas do not contain soil cover and barren rocks are exposed.

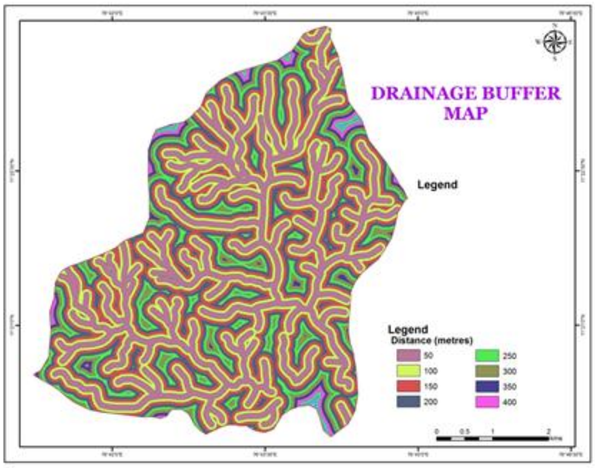

Fig. 3 Drainage buffer map

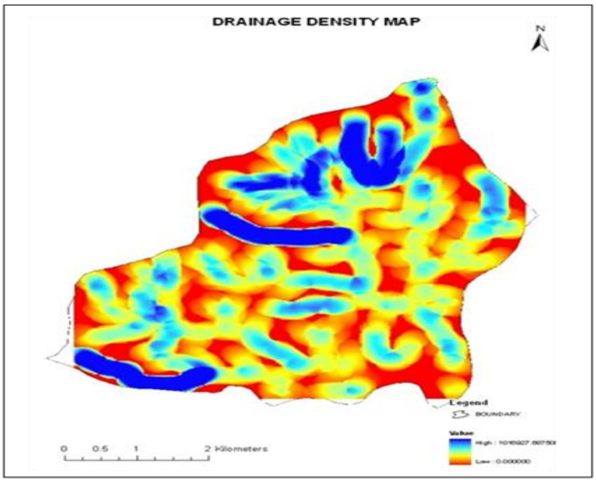

Fig. 4 Drainage density map

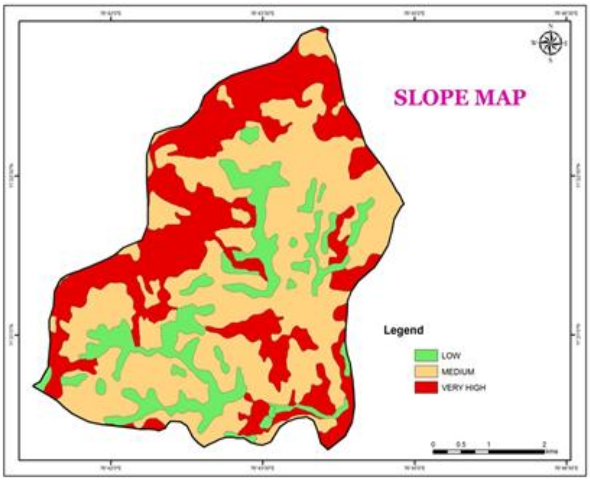

Fig. 5 Slope map

Geology and soil

Landslides are responsible for rapid landscape evolution and represent serious hazard in many areas of the world[2&8]. Kattery watershed comprise of charnockite of Archean age with some intrusive bodies like pegmatite and dolerite. Laterite found over the charnockites is hard. Lithomarge (red clay soil) is very common in most of the places. Structurally the area is highly disturbed and is subjected to faulting. Block faulting resulted in the upliftment of the plateau. Due to these tectonic activities the deep-seated metamorphic rocks have undergone considerable deformation during Precambrian times, which resulted in different structural features such as folds, faults and joints.

The watershed exhibits thick soil cover in many places. Soil of the area falls under two major types: (1) clayey soil and (2) loamy soil. Only a small area in the northwestern part consists of loamy soil and the remaining whole area is covered with clayey soil (Fig. 6). The depth of the soil usually varies from one to three feet and that of the sub-soil from 10 to 14 feet. The sub-soil is invariably porous.

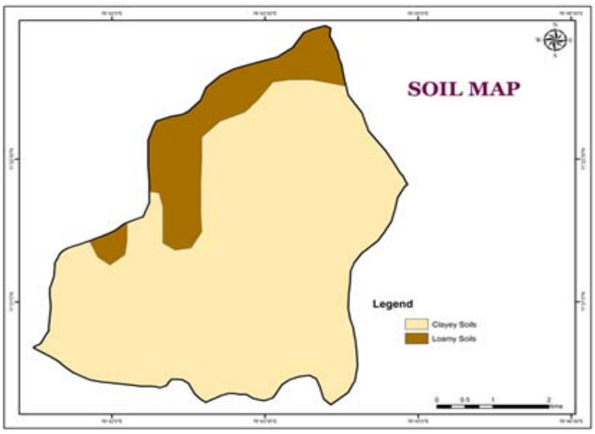

Fig. 6 Soil map

Geomorphology and lineament

Slope is a geo-dynamic process that naturally shapes up the geomorphology of the earth. However they are a major concern when those unstable slopes would have an effect of the safety of the people and property[9]. The area falls in the Uthagamandalam – Kotagiri plantation surface which rises to a height of more than 2000 m above MSL. The Uthagamandalam region is more elevated containing Doddabetta peak and its eastern extension the Honnathalai RF. The elevation gradually drops from about 2500 to 1500 m which is the next plantation level referred to as Coonoor plantation surface. Much of the area forms plateau landform in this surface and the erosional action of the streams have resulted in the formation of valleys with steep to moderate slopes. Escarpments are found in the southern and western boundary of the watershed. The other areas have a rolling topography sculptured by fluvial action with resistant portions rising as gently sloping hills.

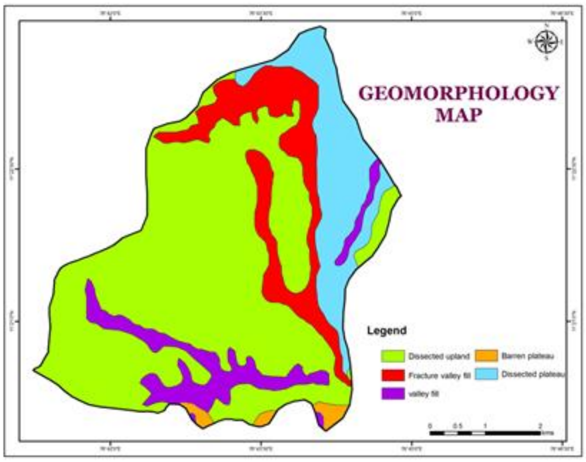

Fig. 7 Geomorphology map

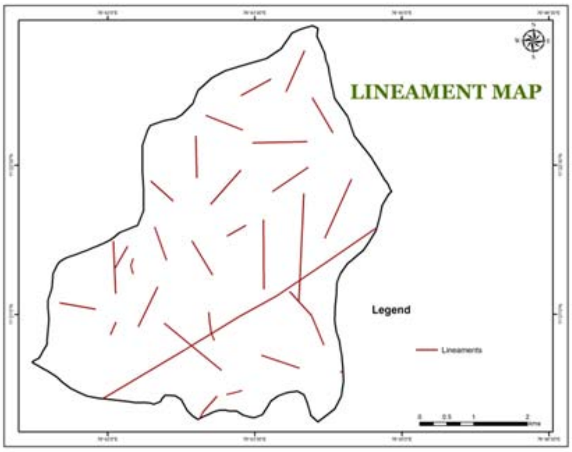

Fig. 8 Lineament map

Pediplains are the characteristic geomorphological units which can be divided into deep buried pediments, buried pediments and shallow buried pediments. Shallow buried pediments are observed in the northern, western and southern boundary of the watershed and the thickness of the soil cover increases as the elevation decreases. In the hills with circular pattern located downstream of the watershed buried pediments rather than shallow buried pediments are found. Flood plain is found when the river order reaches 4 and in such areas the rivers meanders during base flow eroding the floodplain deposits. Valley falls are also encountered in some areas in the foot of hills. The dissected upland covers 70 % of the watershed. The northeast area consists of dissected plateau (Fig. 7). It occupies about 10% of the watershed. Southeast and northwest part consists of fractured valley fill. It comes around 10%. Then the remaining 10% is valley fill and barren plateau. From the geomorphology point of view, it is clear that northern part of the watershed is more susceptible for landslides than the southern part. Lineament map shows that the area consists of weak planes (Fig. 8). If there are more lineament intersections the possibility of occurrence of landslides are more. In the Katerry watershed the lineament density is high in the northwestern part.

Land use / land cover

Landslides are dominately influence by rainfall, slope, road cutting, landuse and many other factors[10]. The land use / land cover exerts a control over landslides and is considered next to slope in importance. While urban activities result in the modification of slope due to leveling of the terrain forming steep cut, modification for agriculture enables the percolation of water particularly in areas wherein vegetables are grown. As a result high frequency was arrived for the class crop lands. Land use factor has been classified as forest plantation, plantations, croplands, built up and water bodies. Land with vegetable crops form the dominant land use followed by tea gardens, forest plantation, settlement, dense forest, mixed cultivation and water bodies.

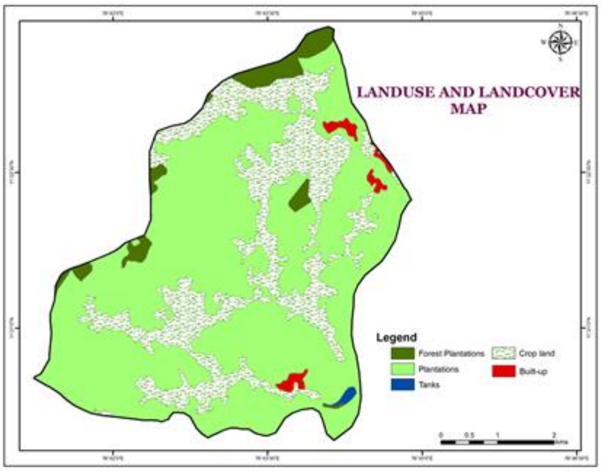

Fig. 9 Land use and land cover map

The highest ratio is noticed in vegetable crops as the field is prepared for cultivation loosening the soil for aeration. Further, periodical tilling is carried out to remove the weeds and to aerate the land. Ground is hence, devoid of vegetation growth except for the cultivated crops.

Criteria	Class	Rank	Weightage in (%)
Geomorphology	Dissected upland	1	20
	Dissected plateau	2	
	Fracture valley fill	3	
	Valley fill	4	
	Barren plateau	5	
Land use / land cover	Crop land	1	15
	Plantation	2	
	Built-up	3	
	Forest Plantation	4	
	Tank	5	
Soil	Clayey soil	1	10
	Loamy soil	2	
Slope	Very high	1	20
	Medium	2	
	Low	3	
Lineament	Present	1	20
	Not present	2	
Drainage	First order	1	15
	Second order	2	
	Third order	3	

This enables percolation of water during rains and the pore pressure of clay bearing soil increases. Susceptibility for landslides increases manifold where tubers like potato, turnip, carrot, and beetroot are cultivated. Settlements and tea gardens rank next in the susceptibility followed by forest plantations. Contrary to expectations, forests also record landslides. When the tea planters converted large tracts of forests into tea estates, they have left only the steep slopes as forests which have difficulty for accessibility. Thus forests exist only in the steep slopes (Fig. 9).

Landslide hazard zonation map

Human vulnerability to any disaster is a complex phenomenon with social, economic, health and cultural dimensions[11]. Computer aided GIS techniques are useful in data integration, data analysis and modeling, correlating the information thus evolved which can be extended to the similar areas to extract the required data and other details. Landslide susceptibility zonation can formally be defined as the division of land surface into near homogeneous zones and then ranking these according to the degrees of actual or potential hazard owing to landslides[12].

Landslide hazard zonation map of Kattery watershed (Fig. 10) was prepared by integrating and assigning proper ranks and weightages for various thematic layers namely drainage, topography (slope), geology, soil, geomorphology, lineament and land use / land cover along with field details using GIS. Ranks and weightages allotted for various themes and components are given in Table 1. The landslide hazard zonation map is classified into 5 main categories of vulnerability: very low, low, moderate, high and very high. The northeastern and southwestern part of the watershed is more vulnerable to landslides, whereas the southeastern part is less vulnerable.

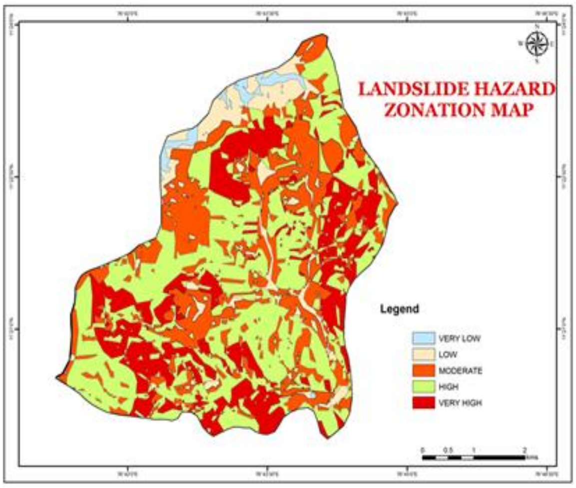

Fig. 10 Landslide hazard zonation map

Conclusion

Landslide hazard zonation mapping was attempted in and around Achanakal region, Ooty Hills, Tamil Nadu, India using remote sensing and GIS techniques. Initially various thematic maps pertaining to this work was prepared for Survey of India topographic maps and satellite imageries. The prepared maps were verified in the field during field visit. Finally all the thematic maps were integrated using GIS and landslide hazard zonation map was prepared. Landslide hazard zonation map illustrates that northeastern and southwestern part of the study area is more susceptible for landslides. The landslide hazard zonation map contains five categories of vulnerability such as very low, low, moderate, high and very high. There are more possibilities of occurrence of landslide in the area where the landslide occurred during November 2009.

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