International Journal of Applied and Advanced Scientific Research (IJAASR)
Impact Factor: 5.655, ISSN (Online): 2456 - 3080
(www.dvpublication.com) Volume 2, Issue 2, 2017

ASSESSMENT OF DEBRIS FLOW DISASTER IN A RESERVE FOREST AREA, KERALA

A. K. Manoj* & S. Sreekumar**

* School of Environmental Sciences, Mahatma Ghandi University, Kottayam, Kerala
** Department of Geology and Environmental Science, Christ College (Autonomous), Irinjalakuda, Kerala

Cite This Article: A. K. Manoj & S. Sreekumar, "Assessment of Debris Flow Disaster in a Reserve Forest Area, Kerala", International Journal of Applied and Advanced Scientific Research, Volume 2, Issue 2, Page Number 315-322, 2017.

Abstract:

Slope failures are common geo hazards in the Western Ghats during monsoon period. In the present study an attempt is made to understand the mechanism of debris flow in Akamala area of Kerala Western Ghats and to evaluate the chances of failure in the area in future. Due to debris flow the families in the settlements at the foot hills were evacuated and relocated elsewhere by administrators. The area is still failure prone, and may fail as number potential failure surfaces exist in the site. The geometrical analysis of the slopes were carried out to identify the type of failure happened on the slope and also to examine whether the vulnerability of the profile to failure still exists in the site. Angle of internal friction (Ø), plastic limit, liquid limit and plasticity index of the samples were determined in the geotechnical laboratory. The geoenvironmental set up of the Akamala region indicate that slope, relative relief, soil characteristics, degraded patches within the forest, discontinuities have rendered the hill slope prone to slope failures. The degradation of forest permitted large of amount of rain water entering the ground beneath the slope. The wild deep rooted trees in forest usually bolt the overburden to the underlaying rock. The lack of vegetation caused the rise in the piezometric surface which increased the pore water pressure and decreased the shearing resistance. The study brings about the fact that an effort must be there to identify and locate the degraded forest areas close to community living centers and highways. This must be given top priority in forest management policy to avoid grate disaster.

Key Words: Western Ghats, Akamala, Debris Flow, Peizometric Surface, Shearing Resistance & Stability

Introduction:

Slope failures are common geo hazards in the Western Ghats during monsoon period. Deforestation and modification of hill slope for cultivation and construction renders them prone to slope failures. A debris flow that occurred at Akamala during monsoon period of 2004, falling under a reserve forest area is subjected to a detailed investigation (Fig.1). The crown and middle part of the debris flow begins from reserve forest area, and the toe extends upto the settlement area at the foot of the hill slope. Akamala disaster in Thrissur District struck on 5th June 2004 had caused extreme damage to property. Causalities were avoided as the settlements were a few meters away from the rolled down debris.

Several research articles have cited the evidences of slope failure and resulting losses all around the world. (Ansari et al. 2013, Bunc et al. 1997). Deforestation and tinkering of hill slope for cultivation renders them prone to slides according to Pitchaimuthu and Muraleedharan (2005). Studies carried out by Sreekumar and Arish Aslam (2017) has reported that slope failures in Kerala Western Ghats during monsoon periods are mainly due to human intervention and heavy down pour.

Landslide hazard zonation on macro scale of Munnar and adjacent area by Muraleedharan (2009), district wise landslide hazard zonation by National Centre for Earth Science Studies (2010), geological and geotechnical studies of slopes along Kottayam-Kumali road by Sreekumar (1998) are the important studies carried out on slope failure in Western Ghats of Kerala. Studies carried out by Arish Aslam and Sreekumar (2016) emphasized the relevance of geological geotechnical studies in the micro level to understand the stability of slope and to avoid risk.

Afforestation is considered as a strategy to combat Landslides in steep slopes.The root bolting by healthy wild trees increase the factor of safety of any hill slope (Gray and Leiser 1982). However many studies say that disastrous slope failures have occurred with their origin in forest areas and ends up at high ways blocking traffic or destructing settlements.

In the present study an attempt is made to understand the mechanism of debris flow in Akamala area and to evaluate the chances of failure in the area in future. The hill slope at Akamala is very steep with patches of degraded forest land and with potential discontinuities. It is estimated that about 49,500 cubic meter of overburden from an area of 82.5m x 600m was dislodged along with uprooted wild trees. Due to debris flow the families in the settlements at the foot hills were evacuated and relocated elsewhere by administrators. A new rivulet spouted in the area after the incidence. Another landslide happened immediately after the major one has left a minor scar close to it. A concentric deep crack has already developed above the crown of the main scar). The cracks are ideal site for water infiltration and thus aid in increasing pore water pressure which may eventually leads to mass wasting process. The area is still failure prone, and may fail as number potential failure surfaces exist in the site.

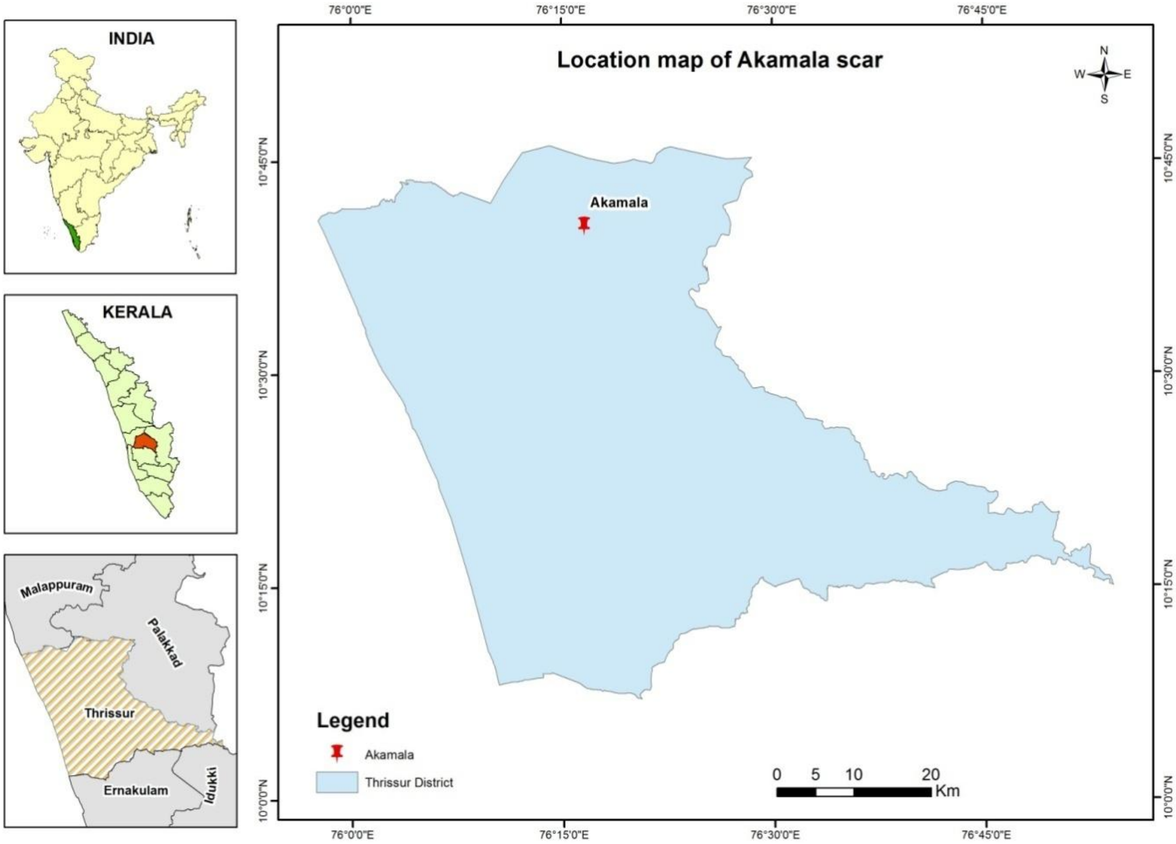


Figure 1: Location map

Study Area:

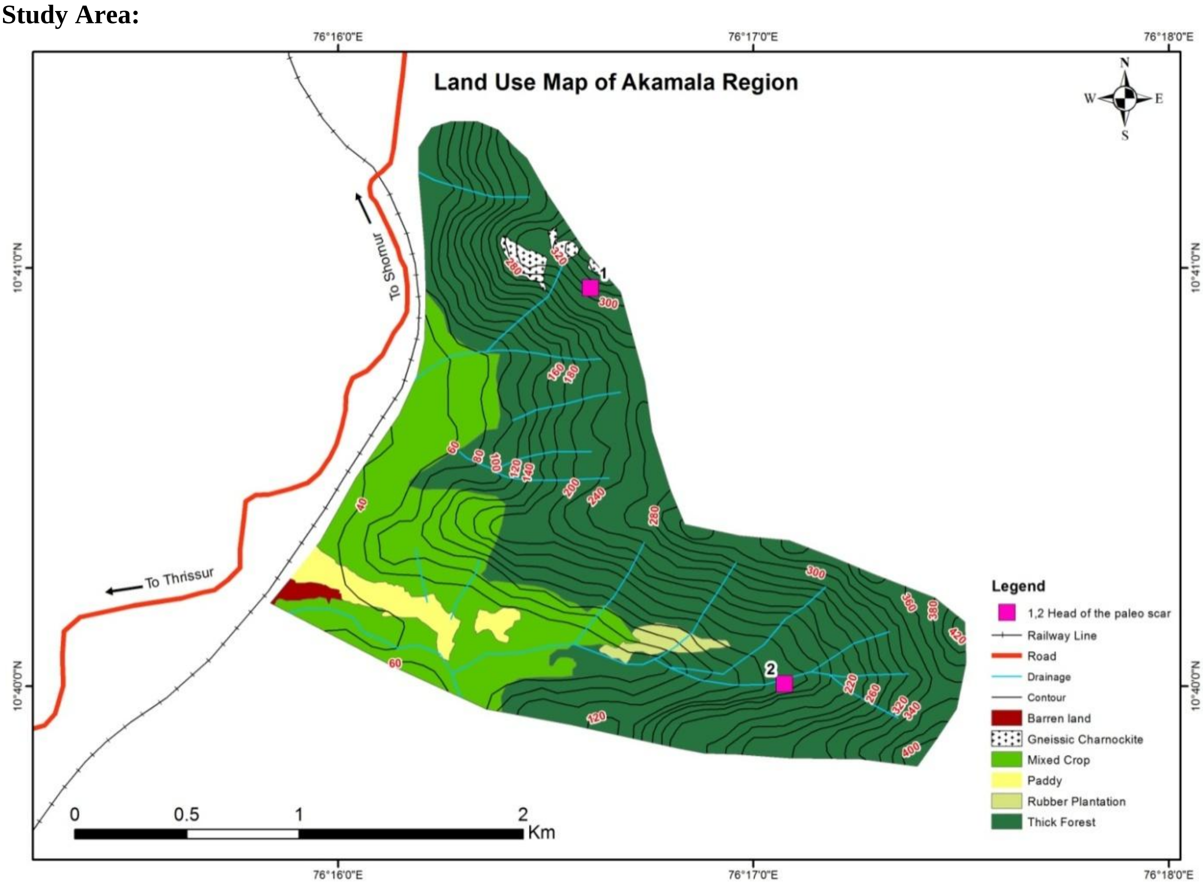


Figure 2: Topographic map of the study area.

The area under investigation (Fig.2) is located at Akamala in Thalappilly Taluk, Thrissur District, lies between (N 10˚ 41'21.16" E 76˚15'49.97"and N 10˚39'48.60" E 76˚.18'35.3").Altitude of the region ranges from 40m to 360m above mean sea level. The climate is typically humid, characterized by medium temperature and moderate rainfall. Heavy rain fall occurs during the monsoon season and average annual rainfall is 320mm. Two paleo scars are located, one with N latitude 10˚.41'01" and E Longitude 76˚.16' 50"and the other at N 10˚40'0.2" and E 76˚17'3.9".Detailed investigation of the first scar is carried out in this study.**Geological Settings:**

Akamala forms part of Kerala Western Ghats. The ridges are oriented NW-SE in conformity with the general trend of Western Ghats. The regolith and laterite along the slope support thick vegetation in the adjacent parts of the hill slope. The roots of wild trees bolt the overburden with the rocks beneath. Along the failed slope (between the crown of the scar (Elevation 320m) and the toe of the flow (Elevation 80 m) fresh and weathered quartzofeldspathic gneiss and charnockite are exposed. In addition to foliation, joints trending SW, NE, sub horizontal joints and near vertical joints are observed. The following is the reconstructed geological section of the failed area.

↑ Colluvial debris
Laterite
Lithomarge
Weathered rocks
Charnockite and Quartzofeldspathic gneiss

The debris consists of boulders with size ranging from 1 to 10 m^3. cube and rest directly over the bedrock at the toe of the slide scar. The thickness of Laterite decreases down slope to reach a maximum of about 4 m in the toe area. In some places Laterite directly overlies lithomarge and weathered rock.

Debris flow at Akamala:

The landslide in the reserve forest area which occurred on 5th June 2004 (Fig 3a and 3b) belongs to debris flow category. The debris flowed very close to the settlement without devastating the houses. There were no casualties. The debris flow had its origin in a degraded forest patch. A streamlet was resulted when the failure happened and in later period it is marked by a small spring which appears only at the onset of monsoon.

Fig 3a: The initiation of debris flow by the wedge failure at the crown of the scar

Fig 3b: joints dipping towrds the hill slope favouring plane failure (middle potion)

Methodology:

A detailed geological map of the failed surface was prepared (Fig.4). The orientation of discontinuities was measured in the field and was marked in stereo plot. The general slopes of the hill, angle of internal friction of the weakest rock type are also incorporated. The geometrical analysis of the slopes were carried out (Hoek and Bray, 1961) to identify the type of failure happened on the slope and also to examine whether the vulnerability of the profile to failure still exists in the site. Samples of overburden were collected from the area close to the scar for performing shear box apparatus tests. Angle of internal friction (Ø), plastic limit, liquid limit and plasticity index of the samples were determined in the geotechnical laboratory. The internal friction of weatherd rock under full saturated conditions was determined and is considered for slope stability analysis. Rainfall amount received at the area is collected from the rain guage stations at Vazhani Reservoir.

Results and Discussions:

The detailed geological map of the failed slope from crown to the toe of paleoscar is presented in Fig 4a-d. The debris consisting of boulders of weathered rock, lithomarge, sand - clay mixture spread out to a wider area at the toe, where families live. As a consequence of this debris flow a deep crack has been developed in the upper and adjacent part of the slide scar, and making the slope vulnerable to further slope failures. The debris flow is left behind by numerous precariously perched boulders too.

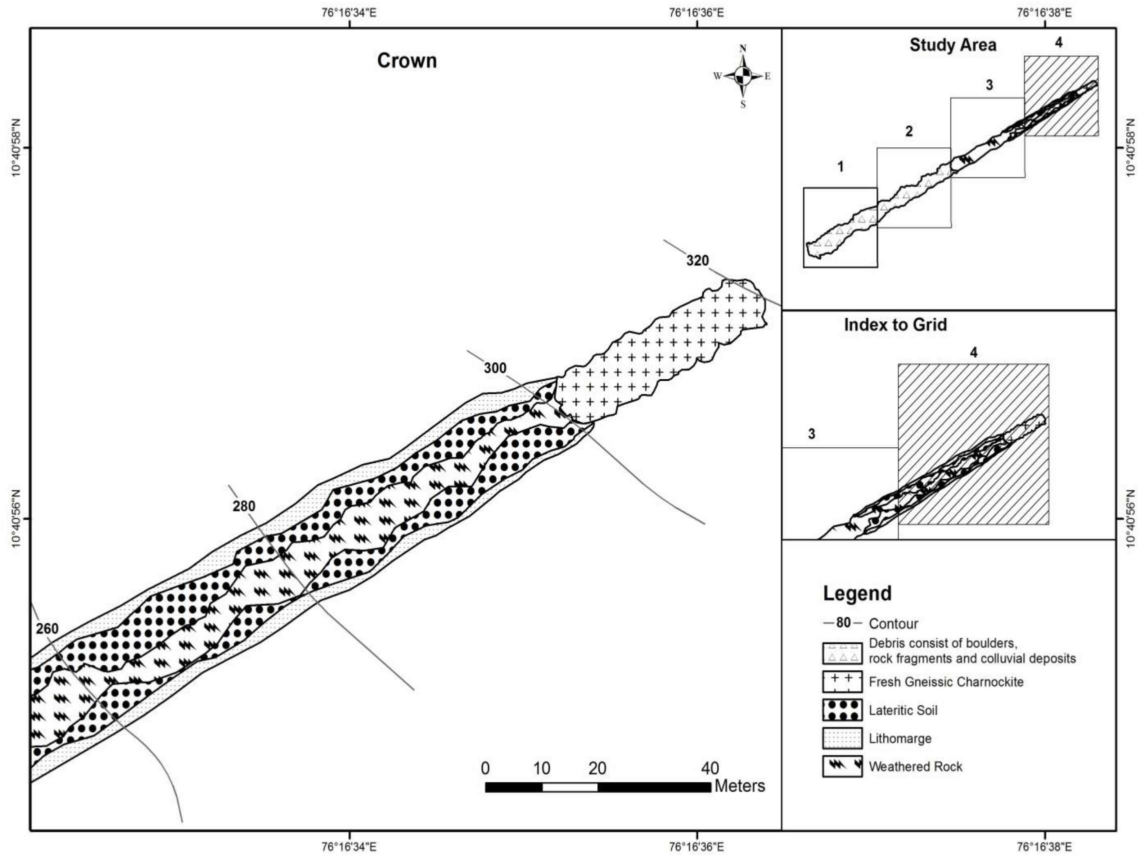
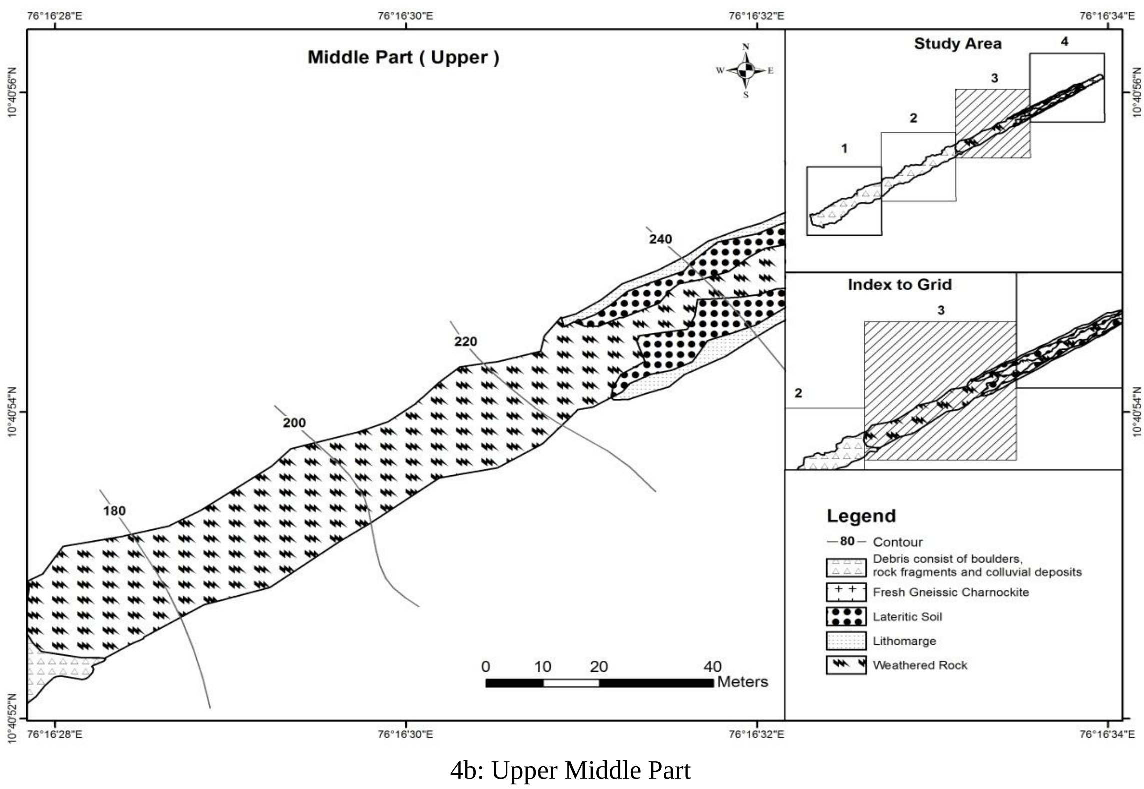
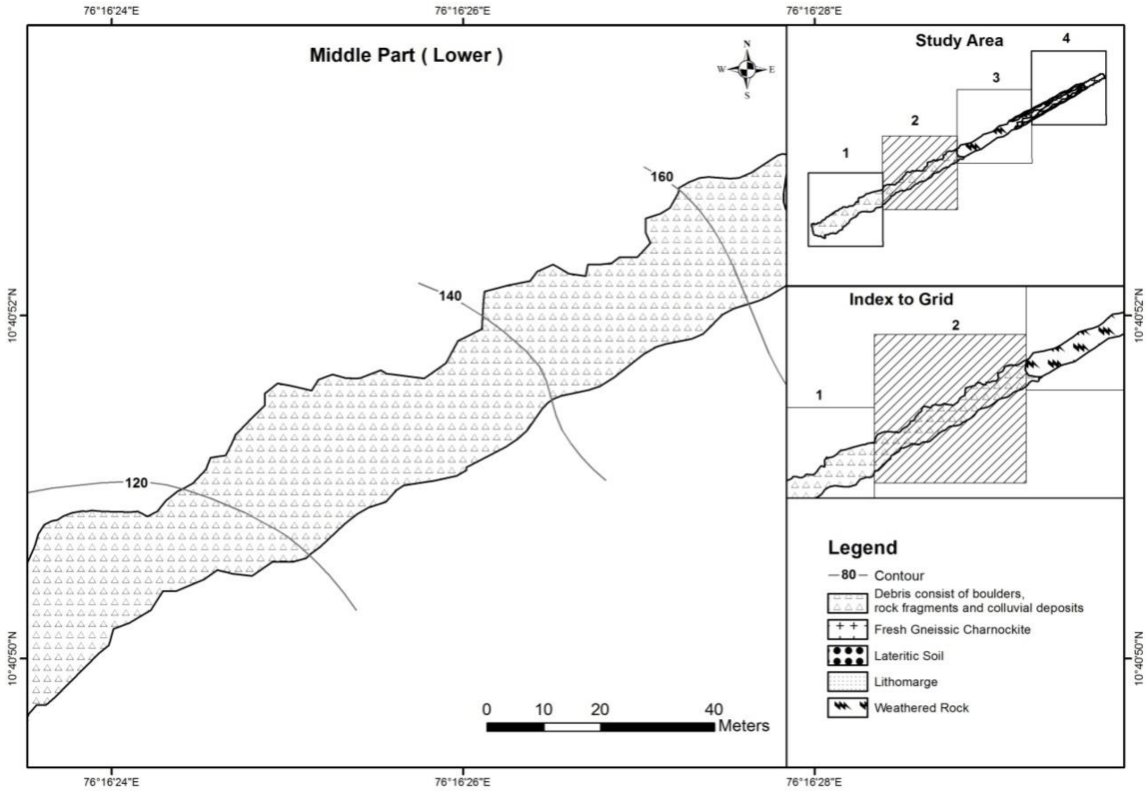


Figure 4a-d: Detailed geologic map of paleoscar

The top part of the crown (Fig 4a) is composed of fresh charcockites which are traversed by joints. The scar is bordered by litho marge clay and laterite soil and is central part is occupied by weathered rock and angular boulders. In the middle part (Fig 4b and Fig 4c) the width of the scar increases but that of wethered rock narrows down. The flank consists of angular boulders laterite soil and lithomarge. Further down only weathered rock is exposed. In the toe part of the scar (Fig 4d) a heep of very coarse angular debris are observed.



4b: Upper Middle Part



4c: Lower Middle Part

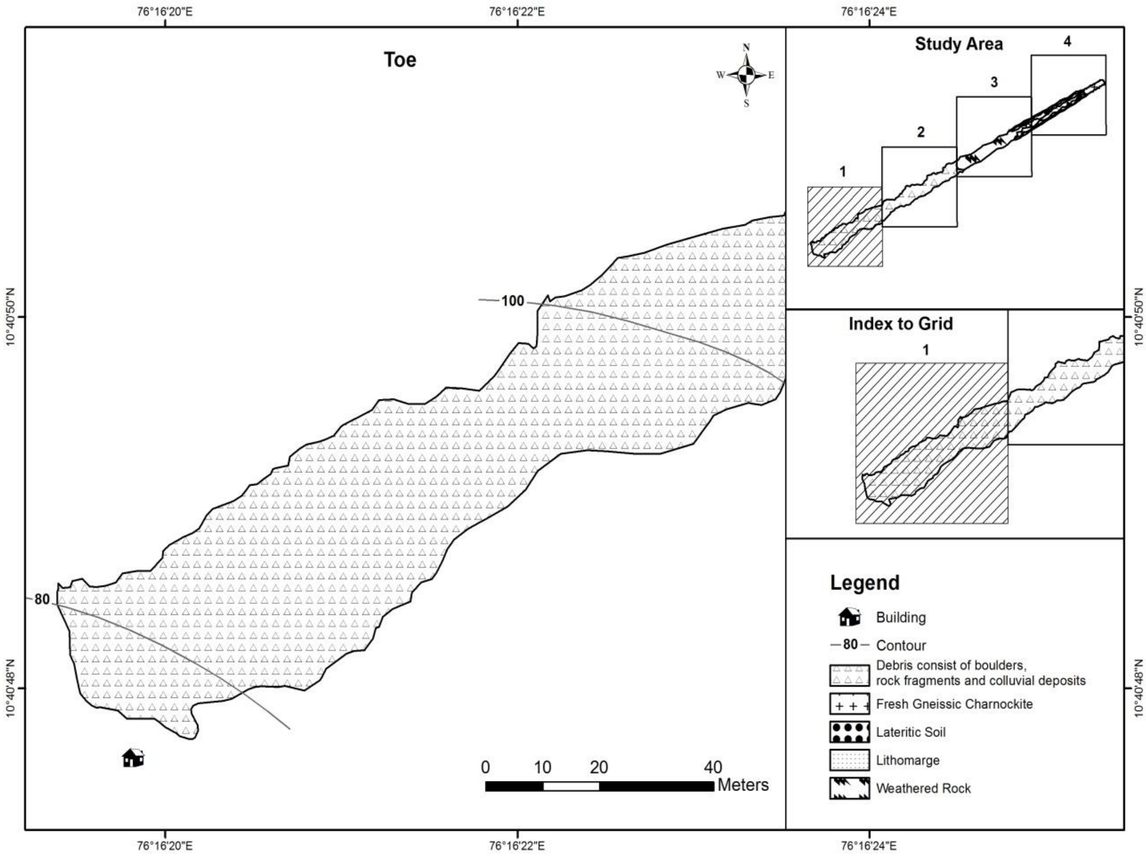


Figure 4d: Toe of the Scar

Geotechnical Properties:

Liquid limit plastic limit plasticity Index, friction angle and silt clay percentage of the soil samples are presented in table 1.Soil is brown to black colour and is humus rich. The textural analysis of soil samples show less silt- clay grade fraction, which might have been removed by fluvial action, indicating severe soil erosion in the area. Shear strength parameters of soil strata is critical for assessment of soil slopes. Friction angle of soil varies from 19.5° to 24°. The friction angle of the weathered rock was determined as 29°.

Table 1: Geotechnical properties of soil

	Sample 1	Sample 2	Sample 3
Liquid limit	5.5	6.8	5.0
Plastic limit	40.5	42.1	58.4
Plastic Index	35.0	35.3	53.4
Ø (degrees)	20.0	19.5	24.0
Silt and Clay (%)	31.0	35.0	42.0

Rainfall as a Triggering Factor:

Succesful relationship between rainfall and landslides in Western Ghats has been brought out by several researchers (Sekhar et al 2008, Thampi 1998, Sankar 1991, Sreekumar 1998, Sajinkumar et al 2011). One hundred and eighty millimetre rainfall for couple of days can be considered as a threshold value to alert the civic administration to get set for disaster management measures in (Sreekumar 1998). Thampi et al. (1998) suggested a minimum rainfall of 300 mm in 2 days as needed to initiate landslides in Western Ghats regions. Sekhar et al (2008) found that on day of mass wasting events in Aruvikkal catchment area, the region received about 200 mm rainfall and the 2-day cumulative rainfall was 278.4 mm. The 2-day cumulative rainfall coinciding with landslides was 315 mm. Monsoon was very active during the period of slope failure in the study area. The rain fall received for a period of seven days including the day of occurrence prior to the incidence of slide is presented in table 2 and Fig 5.Analysis of rainfall data for seven days including the day of incidence indicate that Akamala region received 243.4 mm rain prior to the slide.

Table 2: Amount of Rainfall received on the day of the event and previous 6 days

	May		June				
Akamala	30	31	1	2	3	4	5
Amount of rainfall in mm	--	22.5	60.5	-	12.5	27.8	120

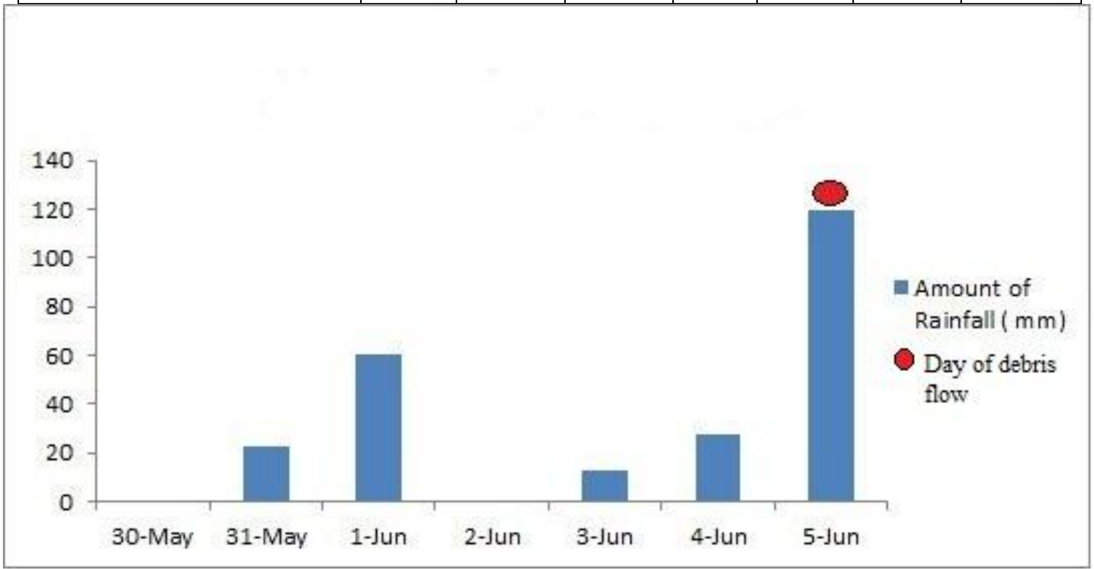


Figure 5: Rainfall (mm) received in the station prior to the debri flow

Casuative Factors:

The open discontinuities at the top of the hillock served as the potential planar surface for initial slides. The attitude of joint planes in rocky hill slope friction angle are presented in Table 3.

Table 3: Features of paleo scar

General Hill Slope	Attitude of Joints	Angle of Internal Friction
40N50W	70N 45E(J1) 50N 95E (J2) 70N 48E (J3) 30N 45W (J4) 80N(J5)	29˚

The stereo plot of 5 major joints, hill slope and angle of internal friction of the weathered rock are presented in Fig.6. In this profile wedge failure occurred along the intersection of joints J3 and J4 within the crescent shaded area. The debris flow initiated with the wedge failure at the top. Consequent to the impact of slided rock and high water pressure activated planar failure down slope. J4 acted as the potential slide surface.

The field study indicates that chances of plane failure along joint J4 still exist in the location. During monsoon period the factor safety of the slope get reduced as the angle of internal friction decreases.

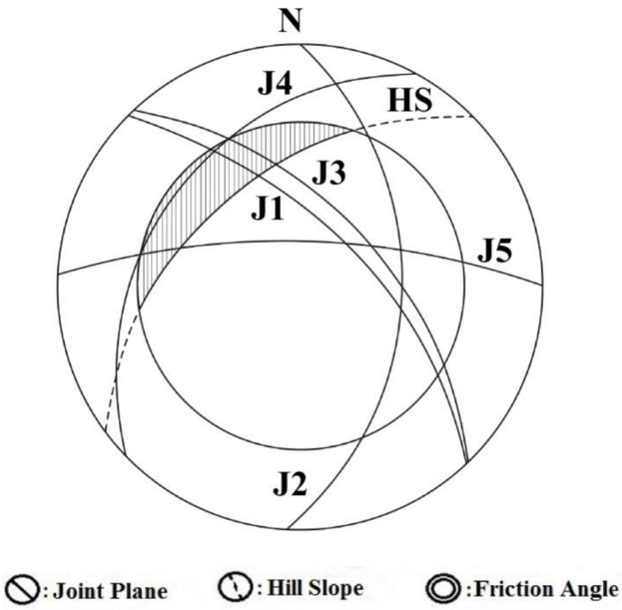


Figure 6: Stereographic Projection of Joints and their relationship with the material properties and hill slope. HS – Hill Slope, JI, J2, J3, J4 and J5 are the joints

From the results it is obvious that the debris flow was resulted due to combined effect of the presence of potential joint planes and water ingression that reduces the normal stress to a level that accelerate failure. The vulnerability of slope failures would have been scaled down, if healthy wild trees were there. It is found that this debris flow occurred in a degraded reserve forest area.

Conclusions:

The geoenvironmental set up of the Akamala region indicate that slope, relative relief, soil characteristics, degraded patches within the forest, discontinuities have rendered the hill slope prone to slope failures. The degradation of forest permitted large of amount of rain water entering the ground beneath the slope. The wild deep rooted trees in forest usually bolt the overburden to the underlaying rock. The lack of vegetation caused the rise in the piezometric surface which increased the pore water pressure and decreased the shearing resistance. The study brings about the fact that an effort must be there to identify and locate the degraded forest areas close to community living centers and highways. This must be given top priority in forest management policy to avoid grate disaster.

References:

1. Ansari M K, Ahmad M & Singh R Singh T N, Rock fall hazard assessment at Ajanta Cave, Aurangabad, Maharashtra, India, Arabian J Geosci. (doi: 10.1007/s12517- 013-0867-8).2013
2. Arish Aslam & Sreekumar S, Characteristics of slope failures in tropical hill slopes of South West India, International Journal of Science and Research, Vol 5, Issue 3,pp 1584-1588, 2016
3. Bunce CM, Cruden D M & Morgenstern N R, Assessment of the hazard from a rockfall on a highway. Can Geotech J. 34:344–356, 1997
4. CESS, Multi hazard zonation maps of Kerala, 2010
5. Gray D H & Leiser A T, Biotechnical slope protection and erosional control, Van Nostrand Reinhold Company, New York.1982
6. Hoek E& Bray J W, Rock slope engineering, the institution of mining and metallurgy, London: 320-358, 1981
7. Pitchaimuthu R & Muraleedharan C, Causes and mechanism of Amboori landslide of 9th Novenmber, 2001, Thiruvananthapuram district, Kearla, Journal Geological Society of India, Vol 66, pp. 203-208, 2005
8. Muraleedharan C, Landslide Hazards Zonation of Munnar and adjoining area, Devikulam Taluk, Idukki District, Kerala. Geological Survey of India (Unpublished Report), 2009
9. Sajinkumar K S, Anbazhagan S, Pradeepkumar A P & Rani V R, Weathering and landslide occurrences in parts of Western Ghats, Kerala, Journal of the Geological Society of India, Journal of the Geological Society of India 78 (3), 249-257, 2011
10. Sankar G, Investigation of Landslides in Koodaranji and Koorachundu, Calicut district, Centre for Earth Science Studies, Trivandrum, 1991

11. Sekhar L Kuriakose, Jetten V G & Van Westen C J, Pore water pressure as a trigger of shallow landslides in the Western Ghats of Kerala, India: some preliminary observations from an experimental catchment, Physical Geography, 29, 4, pp. 374-386,2008
12. Sreekumar S & Arish Aslam, Geospatial Approach for Landslide Disaster Management: A Case Study from India, International Journal of Applied and Advanced Scientific Research, Volume 2, Issue 2, pp 120-127, 2017
13. Sreekumar S, Techniques for slope stability analysis: site specific studies from Idukki District, Kerala. Journal of the Geological Society of India, V 73. No 6, pp 813-820,2009
14. Sreekumar S, Geotechnical and petrological studies of slopes along the Kottayam-Kumili road, Kerala state, India. PhD thesis (unpublished), submitted to the University of Kerala, Trivandrum, India,1998
15. Thampi P K, Mathai J, Sankar G &Sidharthan S, Evaluation study in terms of landslide mitigation in parts of Western Ghats, Kerala. Unpublished research report submitted to the Mininstry of Agriculture. Government of India, Centre for Earth Science Studies, Government of Kerala, Thiruvananthapuram, India, 1998