Sustainable Habitat Plan for Conservation of Hilly areas: A Case Study of Kannur District, Kerala State

G. Sooraj,
Doctoral Student and Planner Associate, Town and Country Planning Department, Government of Kerala, Kerala.

Dr. H.S. Kumara
Assistant Professor, Urban and Regional Planning, School of Planning and Architecture, University of Mysore, Mysuru-570006. Karnataka.

Naveen k
Senior Geotechnical Engineer, Genstru Consultants Pvt Ltd, Pune 111045 Maharashtra

Abstract:

Landslides are geographically related disasters occurring in hilly regions causing huge damage to land use, infrastructure and human life. Sustainable Habitat Plan for conservation of hilly areas in India is imperative to free from natural calamities such as landslides and flooding. Kerala State faced the worst flood and landslides after 1924 during the month of august in 2018 and 2019. Almost all parts of the state, except the north and south ends has got affected by this natural calamity. The heavy rain in Kannur district had caused landslides which left many hilly parts of the district isolated from other areas. Due to this catastrophe, more than 500 people have lost their life and approximately 5000 relief camps were setup throughout the state.

This study is mainly based on secondary sources of data and visual survey of selected landslides areas and laboratory testing of soil samples in the study area. This paper provides information about the landslides occurred in hilly areas of Kannur district and significance of geotechnical engineering for Sustainable Habitat Plan to mitigation and control of natural disasters for conservation of Hilly areas. Further, the study is to examine the role of geotechnical investigation and slope stability analysis to predict probability of a landslide in a location.

This paper highlights the information about the recent landslides occurred in hilly areas of Kannur district and finally the study concludes that geotechnical study, field inspection, investigation and testing and slope stability analysis has a key role in the Sustainable Habitat Plan for conservation of hilly areas of Kannur District in Kerala State.

Keywords:
Conservation, Sustainable Habitat, Natural disaster, Landslide, Hilly areas, and Geotechnical engineering

1.0. Introduction

Disasters are very dangerous as they eradicate growth of infrastructure development over the years in different sectors. The World Health Organization defines disasters as ‘a disaster is an occurrence disrupting the normal conditions of existence and causing a level of suffering that exceeds the capacity of adjustment of the affected community’ *(WHO, 2002).* Disaster is a severe problem occurring over a short or long period of time. It is commonly observed that developing and underdeveloped nations are more prone to such disasters as they do not have enough resources and infrastructure to fight these dangers. The second half of twentieth century has witnessed a lot of severe disasters that actually have shocked the entire world and also resulted in unbearable losses as well as painful results. Almost 14 lakhs of lives have been lost due to those incidents. It is to be noted that Asia has suffered major setback compared to other continents *(Das B 2002.* It is learnt that the first data collection about disasters dates back to B.C 430 when Athens had suffered severe epidemic. However, it is the earthquake in China in AD.1556 that has actually been scientifically studied for the first time. It is believed that around 8 lakhs of Chinese had lost their lives because of this tragedy *(Forino, 2015).*

India has been suffering from the continuous attack of natural calamities for long time. Its geographical features easily pave way to such dangers. Indian subcontinent has been vulnerable to all kinds of calamities and every state is prone to disasters in varying degree. It is found that India is one of the 10 places in the world where possibilities of natural disasters are in higher stake (Kanungo 2008) Earthquake, flood, landslide, drought and storm are quite common in our country. About 58.6% of land area in India is highly susceptible to natural calamities in which the Himalayas and north-east states have been noted as severe earthquake prone areas and about 12% of land is vulnerable to flood while 5700 km of coastal area is prone to storm and Tsunami. Besides this, about 70% of agricultural land is generally drought affected the remaining is highly susceptible to landslide (*Towards a safer state, 2014*)

More than 471 major disasters had happened in India within the last three decades and an approximate number of 1 lakh lives have been lost. Such disasters had not only cost the human lives but caused irreparable impact on infrastructure, economy and the other assets of the nation. Incidents such as Super cyclone in Orissa in 1999, earthquake in Gujarat in 2001, Tsunami in 2004 and flood in Jammu and Kashmir in 2010 are only a few examples *(NDMA, 2009)*. Gadgil and Kasturirangan report (2013) reveals that major percent of the Western Ghats region as Ecologically Sensitive Area (ESA) these areas are vulnerable to environmental disasters.

Kerala is one of the states which is more susceptible to various disasters as it is located in ecologically vulnerable area. During south western monsoon, the state is subjected to more natural calamities. Flood a major concern during rainy season. When the water level increases above the optimum level and human dwellings are immersed, it is considered as flood. In Kerala, most of the landslides are of higher degree and almost all districts except Alappuzha are heavily vulnerable to such disasters (Lal et. al., 2020).

Small creek, rivers, canals and other water bodies are inundated with water during flood and landfill serves to be a major reason behind this. Irreparable damage caused to agriculture, shelter and other valuables because of such flood are seriously haunting poor people.

Landslide is another big concern. It occurs when rocks and soil collectively move towards lower areas due to the gravitational force. Such forceful movement of water logged soil makes unimaginable losses to human being and their properties *(Byrne, 1992*) Kerala, obviously, is blessed with rainfall with higher average compared to that of the national one and we have many more water bodies all across the state. However, mean involvement of human beings has caused a lot of undesirable results nowadays. Ecological imbalance has been a worrying factor that actually poses threats to the very existence of nature. Availability of rainfall is decreasing and by the end of November and December itself, quite different from the past, we start experiencing scarcity of water. Every year the situations become more and worse and if these issues aren't addressed, definitely, the state may invite heavy drought in coming years even in the month of June and that eventually might affect overall sustainability and existence *(UNICEF, 2017,)*

Lightening is another disaster. Even though this natural calamity is not man-made or human generated, exposure to heavy lightening in recent years has resulted in the death many more in India, particularly in Kerala. Kerala with 560 km seashore is one of such unique states in India. Unfortunately, aggressive outflow of seawater brings severe damages and rate of such occurrences is increasing every rainy season. It undoubtedly creates irreparable setback to state economy in general, and human lives in particular. Rehabilitation of several families takes place during rainy seasons *(Illiyas, 2014)*

2.0. Significance of the Study

Kerala state faced the worst flood and landslides after 1924 during the month of august in 2018. Almost all parts of the state except the north and south end affected by these natural phenomena. Due to its topographical features Kannur district has a natural slope towards western side. The highland regions were extensively affected by landslide issues. Moreover in hilly areas the consequences of rainfall was very high when compared with other parts in midland and low land regions of Kannur district. This heavy rain in Kannur district caused landslide issues and which left these hilly districts isolated from other areas. Due to these effects, more than 500 people have lost their life and approximately 5000 relief camps were setup throughout the state *(Central Water*

Commission, 2018). Cent percent construction activities in identified hazardous prone areas cannot be reduced to avoid the consequences of risk of disaster. However, this is not always possible. There should be proper planning in such a way so as to reduce the severity of a disaster due to natural calamities in future and that helps the growth of hilly areas an integrated approach which includes the utilisation of land followed by giving importance to geotechnical engineering on development of hilly areas to ensure the safety *(Chowdhury, 1995).* The aim of the study is to Sustainable Habitat Plan for mitigating the control of natural disasters and conservation of hilly areas.

Methodologies/tools and techniques

The objectives enumerated above has achieved by heading in the following manner:
At first the study area has been analysed based on secondary sources and visual survey of landslide areas to gain knowledge of the existing status. Further to desk study and reconnaissance survey three land slide locations have been selected. Detailed site inspection, photo documentation, collection of soil samples and laboratory testing, of these areas are carried out to understand the root cause of the failure. Based on the literature studies, understanding the root cause of failure and laboratory test results, thus slopes were modelled and then analyzed by limit equilibrium method (using slide software).

3.0. Study Area

3.1. History and Physiography

Kannur district which was constituted in the year 1957 consequent to the formation of Kerala state was part of the madras presidency during British Rule. In 1980 North Wayanad taluk was separated from Kannur to form Wayanad district. In the year 1984, Kasaragod District comprising Kasaragod and Hosdurg taluks were carved out from Kannur District *(DUR, 2011).* With a total Geographical area of 2970 sq. km, Kannur district accounts for 7.64% of area of Kerala state. It is ranked as the 6th district according to the area with a total population of over 24 lakh (2001 Census), about 7% of total population of the state. Population density of Kannur district is 851 persons/sq. km, which is just below the state average (860 persons/sq. km) and is ranked 9th in the state as per 2011 census.

Physiographically, the district has three divisions including coastal plain, mid land and high lands. Majority of the population of Kannur district lives in the coastal and midland region of the district. Kannur taluk lies completely in the midland and coastal plain region, whereas Taliparamba, Iritty and Thalassery taluks lie in highland, midland and coastal plain regions *(DUR, 2011).* The district level analysis of topography and relief features reveals that, over 27 % of the district lies in the coastal plain and about 41.25 % of the total district lies in the mid lands and rest i.e. 31 % of the district falls under high land.

The district having the distinct boundary comprising of the eastern and south eastern part of the District, mainly the part of western Ghat in Kannur district and the higher areas of the state forms this region. Eastern parts of Payyannur, and Taliparamba blocks Majority of the Irikkur, Iritty, and Peravur blocks largely constitutes the highland category. Forest lands and plantation comprises majority of land forms in this area. Density of population is very low in the highlands (Fig. 1.1).

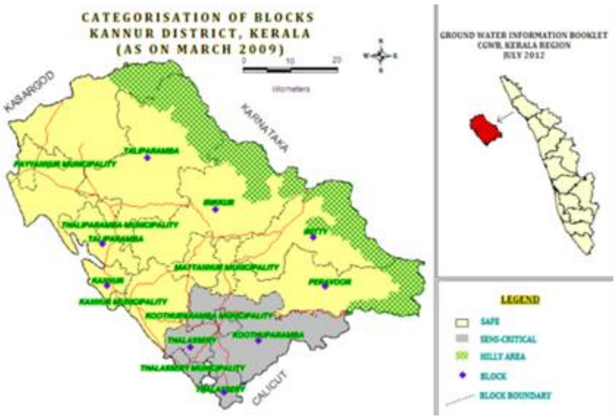


Fig. 1.1: Physiographical divisions of the District
(Source: Ground Water Department, Kerala)

3.2. Landslides in 2018

The high land area of Kannur district is primarily located at north western and eastern part of district. The terrain is undulating in nature and is exposed to various calamities. The damages due to landslide are very high in these places. In most of the cases, the landslip occurred along the earth cut already made in hill slopes. Soil piping (tunnel erosion) is the formation of underground tunnels due to subsurface soil erosion which is a quite general occurrence in Kannur. When the tunnel grows bigger and bigger, the roof collapses and subsidence occurs. In the Western Ghats, it is a regular happening. Flooding also is a major concern in many areas of Kannur district

In 2018, there are 13 land slide affected local bodies in Kannur district. Out of this Kottiyoor, Ayyankunnu and Eruvessy Panchayats and Iritty Municipality are the most affected areas within the Local bodies. There are 8 landslides in Kottiyoor panchayat, followed by 5 slides in Ayyankunnu and Eruvessy Panchayats and Iritty Municipality. In other cases, landslides and debris fall of minor in nature were occurred and most of them were inside the forest and plantation

Table 1.1: List of Landslides affected Municipality/Grama Panchayath and concern villages

Sl. No,	Municipality/Grama Panchayath	Name of the Villages
1.	Eruvessy	Eruvessy
2.	Iritty	Keezhur
3.	Kottiyoor	Kottiyoor
4.	Payam	Vilamana
5.	Ayyankunnu	Ayyankunnu
6.	Kelakom	Kelakom
7.	Aralam	Aralam
8.	Alakode	Vellad
9.	Naduvil	New Naduvil
10.	Thripangotoor	Thripangotoor
11.	Sreekandapuram	Sreekandapuram
12.	Payyavoor	Payyavoor
13	Ulikal	Vayathur

(Source: Disaster Management Cell, Kannur District)

3.3. Field observations of selected Grama Panchayaths

3.3.1. Kelakom Grama Panchayath

During the heavy rain in the month of Augut 2018, hill slopes in Santhigiri area of Kelakam Grama Panchayat had slipped. Cracks were developed in around 26 houses and acres of agricultural fields in this area. One of the major slips had occurred at Kailasanpadi (75.859628°E,11.912070°N) the 7th ward of the Panchayat in the evening of August 11 and at the morning hours of the ensuing day. Three of the houses had become totally uninhabitable by the incident and 69 members of 20 families of the area were evacuated to the nearby Govt. Lower Primary School, Kolithattat Santhigiri (Fig. 1.2 & 1.3).

Fig 1.2 Houses which developed structural cracks at Santhigiri

Fig 1.3 Land slip occurred can be seen on slope behind the damaged house

3.2.2. Koolichambra

The second selected landside is located in Koolichambra (75.40’30.19”E 11.58’36.19”N). This spot falls in the R.S. No.156 (p) of 13th ward of Iritty Municipality in Keezhur Desom and in Keezhur Village. The hill slope was excavated for construction house. The cut height of the steeply cut slope was about 6m. The house constructed by excavation of hill slope at his location and built without any retaining wall or other protection measure, has got damaged due to the landslide (Fig. 1.4.). Seepage water emanating from the toe of the slope was observed at this location (Fig. 1.5.). The cut slope majorly comprised of yellowish to reddish lateritic soil. Soil samples were collected from the cut slope for further laboratory testing.

Fig 1.4.: Landslide at Koolichambra

Fig 1.5 Seepage from toe of failed slope

3.3.3. Keezhurkunnu

Landslide occurred at the location in R.S. No. 2 of Keezhur Desom (75º38’881”E ,11º58’791”N) of Keezhur Village (5th ward of Iritty Municipality). In this location the type of landslide occurred appeared to be large and shallow mud flow. Huge quantity of soil mass on the hill slope had slipped and flown down along with the surface and sub-surface water flow. The soil was found to be lateritic soil with major amount of silty to clayey material. The hill slope at this location was found to be relatively steep and was cut at multiple locations for construction of houses and infrastructure. One house and a two storied RCC building which were located on the track of this flow of landslide had collapsed and completely filled with soil and debris. The Edakkanam - Nerambok road had got blocked due the accumulated debris material. Traffic along the road at the spot was restored after clearing the debris.

Fig 1.6 Landslides at Keezhurkunnu

3.4. Geotechnical Study

All the three locations that were discussed in the earlier section are selected for further geotechnical study. The hill slope was steeply cut for construction of houses, roads and other infrastructure in these locations. The slopes comprise of yellowish to reddish lateritic soil. The thickness of the lateritic soil in the region varied from 5 to 7m as observed from various exposed surface in the site locations. Weathered laterite rockmass was observed to be underlying the soil layer at some of the locations. Subsurface water was found to emanate from the toe of the cut slope during the site visit, indicating the soil mass to be completely saturated during the rain. The seepage appears to have led to toe erosion and softening which is one of the factors leading to failure of cut slopes. In hill slope with relatively steeper natural profile as was the case in the third location, huge amount of soil mass had flown down with the water. In other two locations the landslide was observed to be local slides at the excavated cut slopes.

Soil samples were collected from these cut slopes where failure had occurred for further laboratory testing. The samples were tested for index and engineering properties. It was found that the soil majorly consisted of silt and clay with varying amount of sand and gravel. The soil was found to be medium to highly plastic and can be classified as medium to highly plastic clay. From the shear test results it can be seen that the strength of the soil is low with an average cohesion of about 30kPa and angle of internal friction of around 14 degrees. The soil present in the third location was observed to be highly plastic clay with low shear strength. The below table shows the test results obtained from the test carried out on collected samples.

Table 1.2.: Summary of test results

Location	Grain Size Analysis (%)				Liquid limit	Plastic limit	Specific Gravity	NMC (%)	Shear strength parameters	
	Gravel	Sand	Silt	Clay					C (kPa)	φ (°)
1	8	32	38	22	55	29	2.74	36.3	38	16
2	5	27	39	29	48	25	2.81	23.3	31	15
3	6	10	44	40	65	29	2.86	41.7	18	8

NMC – Natural Moisture Content
C – Cohesion
φ – Angle of internal friction
Soil testing was conducted at Geotechnical engineering lab at Sadguru Swami Nithyananda Institute of Technology, Kanhangad.

3.5. Slope Stability Analysis

Slope stability analysis has been carried out using software – 'Slide' of Rocscience Inc., USA. Slide is comprehensive slope stability analysis software, complete with groundwater seepage analysis, rapid drawdown, sensitivity and probabilistic analysis and support design (Abramson et. al. 2001, Duncan and Wright, 2005). The global stability analysis has been carried for these locations by Limit equilibrium method (Bishop Simplified Method). The method considers circular slip surfaces for stability analysis. The mass of soil above the slip surface is divided into vertical slices. The requirements of equilibrium are applied to the slices. The factor of safety is defined as the ratio of actual shear strength(s) possessed by the soil on trial surface to that required to maintain limiting equilibrium. The materials are modelled using Mohr-Coulomb parameters.

Slope stability analysis has been carried out for the locations with approximate geometry of land profile and results obtained from the lab tests conducted on the soil samples collected from the site locations. In first two locations the land was steeply cut for construction of buildings and has similar profile and subsurface profile. Analysis for these two locations shows that the slope is stable under dry condition with factor of safety of 1.352. However under saturated condition, which was the case during heavy rainfall, the cut slope is found to be almost unstable with factor of safety of 1.03. As there was no retaining structure constructed to retain the steep cut the cut slope failed during the heavy monsoon period.

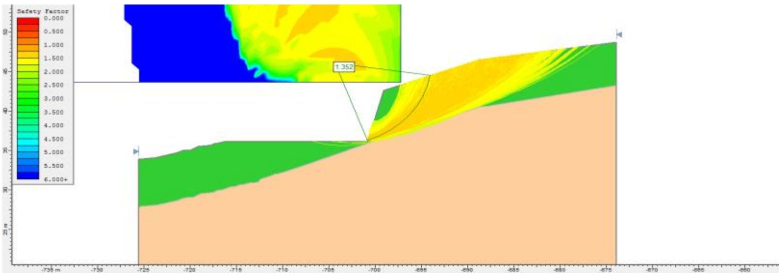


Fig. 1.7.: Analysis of cut slope – Dry condition (using slide software)

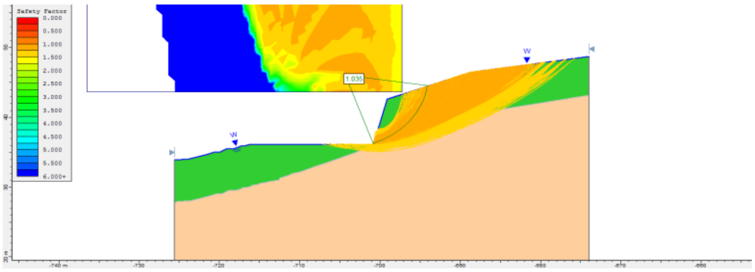


Fig. 1.8: Analysis of cut slope – Saturated condition (using slide software)

Similarly slope stability analysis was carried out for the hill slope of third location. The hill slope in this location has an inclination of about 25 to 30 degrees. The slope has been modelled based on the visual observations in the field and lab test results of soil sample collected from the site location. Based on the slope stability analysis it has been found that the slope is unstable under saturated condition with factor of safety below 1. As can be found from the lab test results the soil in this location comprises of highly plastic clay with low shear strength. In this location large surficial landslide has occurred with large amount of soil overburden flown down the hill slope. It can be seen from the analysis output that the long shallow slip circle is formed which fairly matches with failure that has occurred in the location. Below figure shows slope stability analysis of the location under dry and saturated condition.

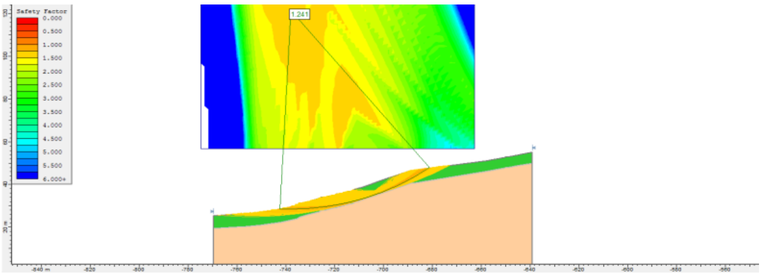
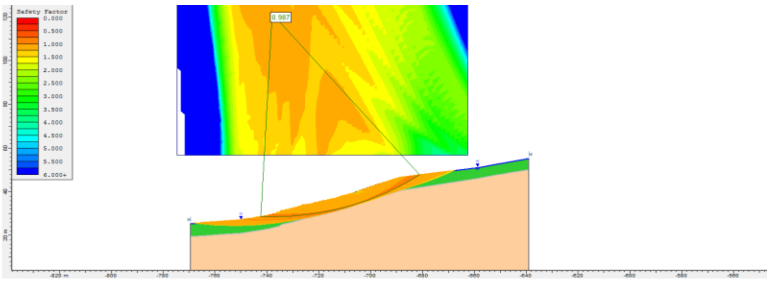


Fig. 1.9: Analysis of hill slope – Dry condition (using slide software)



Fig, 1.10: Analysis of hill slope – Saturated condition (using slide software)

The instability in the slope was mainly due to removal of vegetation (deforestation) of the hill, alteration of slopes (base cutting for construction of houses and infrastructure), large scale removal / excavation of soil at the toe of the hill (for developmental works in the region).The collective rainfall of many days, before the landslide has completely saturated the soil mass and increased the pore water pressure, which along with increased self-weight due to saturation have enhanced the driving force for the slide resulting in landslides and loss of properties

4.0. Conclusions

The identified reasons for landslide occurred in Kannur district are due to the modification of natural slope for planting crops by blocking natural gullies and streamlets, heavy rainfall for one week resulted in building up of excess pore water pressure and reduction of cohesive strength of soil particles due to high levels of saturation. Steeply cut hill slopes for construction of houses and buildings, as was the case in first and second location, have also failed locally as proper retention measures were not constructed. Landslide at the third location appeared to be initiated as a shallow planar failure along rock-soil contact and then transformed into debris flow in sequence.

Earlier reports by Gadgil and Kasturi Rangan committees have included the high land region of Kannur in ecological sensitive zone and also mention the need for proper planning of development in the region. The disaster management plan for the district also lists the villages in eastern highlands of the district as landslide prone locations. Although there are reports which have warned on the possible disaster, lack of proper steps by administration and awareness among the people in these localities, has led to damages during recent heavy monsoon.

Although land use pattern and slope value are used to rank or classify the villages into landslide prone areas; the type, strength and depth of soil layer present in these areas are not considered. The engineering properties of the soil and rock in the hill slopes highly affect its stability. Also the land use and slope are considered for the region as a whole. Most of the landslides have occurred in places where hill slopes were steeply cut for construction. The soil investigation and slope stability analysis asserts the significance of geotechnical engineering for Sustainable Habitat Plan to mitigation and control of landslides for conservation of Hilly areas. There should be proper planning in such a way so as to reduce the severity of a disaster due to natural calamities in future and that helps sustainable development of hilly areas

5.0. Recommendation for Sustainable Habitat Plan

The destruction of the houses and other infrastructures during disasters was mainly due to the absence of appropriate design criteria for cutting of hill slope for construction of buildings and infrastructure, Existing structures that have already been constructed without considering the geotechnical and slope stability aspects. Such infrastructures can be retrofitted *(District Disaster Managment Plan -Kannur, 2015).*

Maps and survey sketches are to be prepared considering stability of the soil, monitoring and updating of landslide related parameters to concerned departments so as to regulate unscientific development. Based on the monitoring, soil investigation and slope stability analysis proper retaining structures and surface and sub-surface drainage measures should be constructed for existing hill cut slopes. In addition, public awareness campaigns should be taken up for conservation and preservation of vegetation so as to prevent further soil erosion. Further, landslide prone areas in the district need to be identified and closely monitored during each monsoon season. Necessary disaster management procedures need to be developed to reduce the damage due to landslides. Along with land use zoning, zonation with respect to slope stability and landslide should also be done at local and regional level.

References

[1] Abramson, L.W, Lee, T.S., Sharma, S. and Boyce, G.M. (2001). Slope Stability and Stabilization Methods, 2nd edition, John Wiley & Sons.

[2] Babu, Gireesh (17 August 2018). *Article in* Business standard India " *Mansoon Havoc in Kerala.* Thiruvanthapuram" https://web.archive.org/web/20180817202209/https://www.business standard.com/article/current-affairs/monsoon-havoc-in-kerala-324-lives-lost-sincemay-29-says-cm-vijayan-118081701276_1.html

[3] Byrne, R. J., Kendall, J., and Brown, S., (1992). Causes and the mechanism of failure of the Kettleman Hills Landfll B-19. Proceedings of Stability and Performance of Slopes and Embankments-II, 1188-1215

[4] Census of India -2011

[5] Central Water Commission Hydrological Studies Organisation Hydrology (S) Directorate *"STUDY REPORT KERALA FLOODS OF AUGUST 2018" published on* September, 2018. New Delhi: Government of India

[6] Chowdhury, R. N. and Xu, D. W. (1995). Geotechnical system reliability of slopes.Reliability engineering and system safety, 47, 141-151.

[7] Das, B. (2002), Some aspects of disaster mitigation and management in India. Indian Journal of Public Administration, volume 48, Issue 2, April.

[8] District disaster management plan kannur June 2015 Prepared and Published by: District Disaster Management Authority, Kannur. Published on: June 2015

[9] *District urbanisation report (DUR) 2011* Prepared and Published by Town and country planning department,Kerala.

[10] Duncan, J.M. and Wright, S.G. (2005). Soil Strength and Slope Stability, John Wiley and Sons Inc.

[11] Faisel T Illiyas, Keshav Mohan, Shibu K Mani, A P Pradeepkumar "Lightning Risk in India Challenges in Disaster Compensation" Economic & Political Weekly ,june 7, 2014 vol xlIX no 23

[12] Forino, G., von Meding, J. and Brewer, G.J. (2015), ―A conceptual governance framework for climate change adaptation and disaster risk reduction integration‖, International Journal of Disaster Risk Science, Vol. 6 (4), pp. 372-384.

[13] Google earth software

[14] IS: 1893, "Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi.

[15] Kanungo, D. P., Arora, M.K., Gupta, D.P. and Sarkar, S. Landslide risk assessment using concepts of danger and fuzzy set theory in Darjeeling Himalayas Landslides, Vol. 5, pp.407–416,2008.

[16] Lal, Preet; Prakash, Aniket; Kumar, Amit; Srivastava, Prashant K.; Saikia, Purabi; Pandey, A.C.; Srivastava, Parul; Khan, M.L. (21 February 2020). "Evaluating the 2018 extreme flood hazard events in Kerala, India". *Remote Sensing Letters*. **11** (5): 436–445.

[17] MOEF, GOI (2013). Dr. K. Kasthurirangan Committee. Report of the High Level Working Group Western Ghats, Ministry of Environment and Forests, Government of India, 2013.

[18] National Disaster Management Authority(2010), Government of India, National Policy on Disaster Management, Ministry of Home Affairs, Government of India publication.

[19] Sharad Raghavan (20 August 2018). *Article in* THE HINDU " *calamity of severe nature"* https://www.thehindu.com/news/national/the-hindu-explains-calamity-of-a-severe-nature/article24739342.ece

[20] Towards a Safer State 2016 Handbook on Disaster Management - Volume 3 - Mainstreaming disaster risk reduction - Budget heads and action points guidelines,Published by Institute of Land and Disaster Management, Department of Disaster Management, Govt. of Kerala

[21] United Nations (2010), United National International Strategy for Disaster Reduction, Geneva, Forest Fires in India (2010). United Nations International Strategy for Disaster Reduction, Report

[22] UNICEF. (2017). Report on *Climate resilent Kerala.* Thiruvanthapuram b Stakeholder recommendations for Kerala state action plan on climate change by climate action network south Asia

[23] World Health Organization (WHO) Training package by WHO/EHA Panafrican Emergency Training Centre, Addis Ababa Updated March 2002 by EHA