

**POST FLOOD HABITAT MODIFICATIONS AND
BIODIVERSITY LOSS IN SELECTED FOREST RANGES IN
PALAKKAD DISTRICT, KERALA**



**FINAL REPORT SUBMITTED TO KERALA STATE
BIODIVERSITY BOARD**

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INTRODUCTION

Biodiversity is the variety and variability of life on earth and plants are essential for the balance in nature and they form a major component of biodiversity. Terrestrial biodiversity tends to be greater near the equator, which seems to be the result of the warm climate and high primary productivity. It is not distributed evenly on earth, and is richest in the tropics and is typically measures variation at the genetic, species and the ecosystem level.

India possesses a distinct identity, not only because of its geography, history and culture, but also because of the great diversity of its natural ecosystems. The panorama of Indian biological diversity is much wider, as it comes under the seventeen mega biodiverse centers of the world. It contains a great wealth of biological diversity in its forests, its wetlands and in its marine areas which are distributed all over the country. This richness is shown in absolute numbers of species and the proportion they represent to the world total (Kumar & Chopra, 2009).

India is rich in biodiversity resources and ranks 7th in mammals, 9th in birds, and 5th in reptile diversity. India has 23.39 per cent of its geographical area under forests and tree cover. Of the 34 globally identified biodiversity hot spots, India harbours 4 hot spots i.e. Himalaya, Indo-Burma, Western Ghats and Sri Lanka and Sundaland. In terms of plant diversity, India ranks 10th in the world and 4th in Asia. With over 45500 plant species, India represents nearly 11 per cent world's known floral diversity (MoEF, 2009). India has 246 globally threatened floral species which constitute approximately 2.9 per cent of the world's total number of threatened floral species.

Biodiversity: Kerala Scenario

Kerala is the southernmost state along the Western Coast of Peninsular India. The state forms part of the Western Ghats, one of the 34 globally recognized biodiversity hotspot regions (Mittermeier *et al.*, 2004). Evergreen forests are its main biological treasure house. Favourable climate and soil conditions and other amusing physical factors are responsible for the biological richness. Structurally, Kerala has different geo-physical

areas such as forests, marshes, mangroves, ponds, seashores and deltas. The Western Ghats which form the mountain ranges of south-western India have been considered a 'Hot spot' due to their wide range of endemic forms of biodiversity of genera, species and races, which include nearly 2000 species of higher plants, 84 species of fishes, 87 species of amphibians, 89 species of reptiles, 15 species of birds and 12 species of mammals – all endemic to the Western Ghats. The number of endemic species existing amongst the lower animals (with the exception of butterflies), lower plants and microorganisms remains unknown (Sreedharan, 2004).

The Kerala forests have bewildering diversity of floristic composition. More than one thousand arborescent species make Kerala's forests rich and varied. The forests of Kerala accounts for 1.26 percent of the total forest area of India and 24 percent of the land area of the State. Based on floristic composition the state of Kerala comes under the Malabar phytogeographical province (Takhtajan, 1986). The state harbours 5094 taxa under 1537 genera and 221 families of flowering plants (Sasidharan, 2012). A total of 1709 taxa that are endemic to Peninsular India are found in Kerala; of which 237 species distributed in 47 families are exclusively endemic to the present political boundary of the state (Nayar *et al.*, 2008). There are about 1170 species with established medicinal properties. The flowering plants of Kerala include 858 exotics that have been introduced for agriculture, forestry as well as accidentally entered species (Sasidharan, 2012); of which around 200 species have become naturalized in the state. Gymnosperms are represented by just 5 species belonging to 3 genera. The state also harbours 337 species of pteridophytes (Easa, 2003), and 465 taxa of bryophytes (Manju *et al.*, 2008).

I.1.Climatic change, Disasters and security concerns- Implications for India

Climate change and disasters are fast emerging as the most defining challenges of the 21st century. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) has provided compelling evidence that climate change is advancing rapidly as a global risk with impacts far beyond just the environment. However, with the climate change manifesting at an unprecedented rate with increased variability and frequency of extreme events, long term implications and possibility of

abrupt change, fuelled largely through anthropogenic cause, these two processes have the potential to coalesce generating destructive forces which could cause mega disasters unless, urgent, radical and resolute mitigation actions are not implemented (Chauhan, 2009)

Extreme precipitation events, landslides, and floods are the most common natural disasters that affect human society and economy (Coumou and Rahmstorf, 2012; Crozier, 2010; Hirabayashi *et al.*, 2008; Roxy *et al.*, 2017). Frequent extreme precipitation events cause flooding (Fowler *et al.*, 2010), which have become common in India (Mohapatra and Singh, 2003). India has witnessed some of the most unprecedented extreme precipitation events that caused flooding and loss of lives in the recent past. The recent extreme rainfall and widespread flooding in Kerala exemplify the enormity of extreme rainfall and large-scale floods in India.

I.2.The Kerala Flood 2018

Kerala is one of the most densely populated Indian states (860 persons per square kilometres) making it more vulnerable to damages and losses on account of disasters. Floods are the most common of natural hazard in the state. Nearly 14.5% of the state's land area is prone to floods, and the proportion is as high as 50% for certain districts. Landslides are a major hazard along the Western Ghats in Wayanad, Kozhikode, Idukki, Palakkad and Kottayam districts.

The flood in August 2018 was the worst flood in Kerala in nearly a century. The torrential rains triggered several landslides and forced the release of excess water from 37 dams across the state, aggravating the flood impact. Nearly 341 landslides were reported from 10 districts. Idukki, the worst hit district, was ravaged by 143 landslides.

I.3.Effects of flood on environment

The devastating floods and landslides caused extensive damage to houses, roads, railways, bridges, power supplies, communications networks, and other infrastructure; washed away crops and livestock and affected the lives and livelihoods of millions of people in the state.

In many natural systems, floods play an important role in maintaining key ecosystem functions and biodiversity. They link the river with the land surrounding it, recharge groundwater systems, fill wetlands, increase the connectivity between aquatic habitats, and move both sediment and nutrients around the landscape, and into the marine environment. For many species, floods trigger breeding events, migration, and dispersal. These natural systems are resilient to the effects of all but the largest floods.

The post-disaster study report, prepared by a team consisting of geologists and soil scientists, coordinated by Kerala Forest Research Institute (KFRI), after visiting the landslide areas in Thrissur district, listed the causative factors for each site. According to the report, the landslides were in slopes above 22° and most common between 22°–28° slopes. Majority of the landslide sites were in the fringes of forests, indicating that disruption of slope continuity due to forest fragmentation was a major contributing factor to landslides in the district. Quarrying in vulnerable areas has also contributed to these degradations and is reported as a factor that can accelerate landslides at least in a few locations. Soil erosion has been reported from most of the forest areas leading to loss of humus and soil nutrients. The problem is largely visible in areas where heavy rainfall has occurred (PDNA report, 2018).

All 44 rivers in the state crossed their banks during the week of 12–19 August 2018. Flooded riparian areas acted as buffers taking the full fury of the fast flowing rivers, especially as a result of the surge that happened when the dams were opened. Damage and erosion to river banks occurred, irrigation canals and drains silted up, canal banks collapsed and many structures such as cross drains and gates were damaged. Inspection and approach roads to these irrigation structures were also damaged, in addition to severe damage occurred to coastal protection structures that led to salt water intrusion into the Vembanad Lake area (PDNA Report, 2018).

Protected areas in the state were comparatively the least affected (PDNA report 2018). However, landslides have occurred in Kottiyoor Wildlife Sanctuary and at Karikombu in the Eravikulam National Park and some private areas in the border of the buffer areas of the Silent Valley National Park.

There is a huge risk of increase in biological invasions in the post-disaster period is being predicted by many reports. The newly exposed land substratum in landslide areas will be favourable for invasive plants such as *Lantana camara*, *Chromolaena odorata*, *Sphagneticola trilobata*, *Mikania micrantha*, and *Mimosa diplotricha*.

The floods that swept the state in the month of August can be treated as a once in-a-century event and several simultaneous and unique phenomena might have resulted in extreme floods in Kerala. These include extreme rainfall, immediate runoff, low flood storage capacity in the reservoirs, poor drainage capacity of canals and sea outlets, and high spring tides. A re-examination of our development priorities, its ecological implications, and social ramifications is the need of the hour, as the state embarks on the disaster recovery process (PDNA report 2018).

I.4. Flood and Landslides in Palakkad District

Habitat modification and loss of habitats are serious environmental threats to vegetation, which in turn cause serious threats to natural animal shelters, and movement tracks of larger animals. The excessive torrential rains during the month of August 2018 in hill tracts of Palakkad district flooded rivers, several streams and created new rivulets and streams in forest ranges. The heavy onslaught of rains and the powerful gushing waters uprooted several large trees and other smaller vegetation and carried them downstream. At several regions mudslides happened, changing the topography in isolated sites. The canopy has opened up in hitherto shaded regions and the lower sciophytic vegetation is now threatened with exposure to sunlight. Though media highlighted the loss of habitation of human in heavy floods, no attempt has been made to highlight the loss of habitats within forests, effects on species survival and life of wildlife. This attempt to document the data and preliminary analysis resulted in generating data for preparation of broad scale planning proposals in conservation of forest areas near to Palghat Gap region.

I.5. Aim of the investigation

To assess the post flood habitat modifications by landslides and species loss in selected forest ranges of Palakkad District near to Palghat Gap of southern Western Ghats.

I.6. Objectives planned in the investigation

- Documentation of species affected by landslides
- Identification of resilient taxa in landslide areas
- Documentation of post flood modification in habitats and biodiversity

I.7. Relevance of the study

The documentation of post flood scenario in different forest ranges near to Palghat Gap region revealed the locations of heavy land slides, mud slides and uprooting of trees in different sites. The data could be assimilated on resilient and vulnerable taxa in forest ecosystems and information regarding loss of diversity could also be documented. The study revealed the vulnerable locations where landslides can occur within the forest ecosystems. The data on primary colonizers in land slide area along with data on biological invasion can throw light on management practices required in forest regeneration in the near future.

II. MATERIALS AND METHODS

II.1.Study area

The proposed study envisages to undertake the effect of flood that hit the state of Kerala in August 2018, emphasizing the habitat modification by way of landslides in the forest ranges nearing to Palghat Gap, viz. Walayar, Kollengode, Nelliampathy and Olavakkode along with landslides in low altitude isolated rocky outcrops in the Gap region of Palakkad district. Based on the preliminary reports on landslide hit areas, the proposed study aims to document the effect of landslides and heavy downpour in the selected forest ranges giving emphasis on habitat loss, loss of assets like Ghat road, bridges etc., loss of species by way of uprooting, washing off the soil in heavy rain, habitat modification by silt deposition and sand filling.

II.2. Methodology adopted

Survey and resource mapping

Floristic explorations were conducted systematically in the main Ghat regions and isolated low altitude hillock systems hit by heavy landslides and flood within three months to monitor the species loss, species survival and habitat modifications.

Photo documentation

Photographs of wide view of forest patches hit by land slides, damages to flora, uprooting of trees, habitat modifications viz. mud slides, silt deposition, sand filling etc. were documented.

Data collection on species loss and resilient taxa

All the taxa hit by landslides and heavy down pour were documented and identification of taxa was done by authentic literature and laboratory examination. Observations were also made on those taxa which survived the flood and land slides.

III. RESULTS AND DISCUSSION

The documentation of landslide hit areas in the forest ranges of Palakkad district has been focused by giving emphasis to Palghat Gap, dividing the ranges near the gap as to the north and south of the gap along with rocky low altitude hillocks in the gap region.

III.1. Post flood effects and landslides in Walayar Forest range

Walayar Forest Range comes under the Palakkad Forest Division which shares its boundary with Olavakode range and Coimbatore district of Tamil Nadu covering an area of about 125.65 sq. km between latitude 10°23'30"North and Longitude 76°52'0" East. Walayar range is divided into six Sections, viz. Akathethara, Pudussery North, Pudussery South, Walayar, Akamalavaram and Kottekkad. Moist and dry deciduous forests and semi evergreen forests are the most dominant vegetation type in Walayar range. Several small and medium sized streams flow through the forest which finally drains to Malampuzha Dam.

Kerala's largest irrigation Dam Malampuzha reservoir is situated in this range and during flood in August 2018, heavy landslides hit the Akamalavaram and Kottekkad sections of Walayar range. This in turn caused heavy water and soil inflow into the dam which resulted in emergency opening of the shutters which caused flood in Kalpathy river and hit the riverine beds in and around this river. The landslides occurred in areas of Parachathi, Kottamutti, Velampotta etc. Moreover, there are many rivulets in the range which also experienced mini land slides, like those in Kottamutti, Ayyappan Mala etc.

III.1.1.Akamalavaram Section

Akamalavaram section is the largest section under Walayar forest range which covers a total area of about 62.59 Sq. Km. No forest area in this section is reserve forest but is vested. Some of the forest area in this section was badly affected by the heavy rain during the month of August 2018. Certain areas in this section experienced minor flood-caused landslides and mud slides which includes Muchikadavu (10° 52' 5.16" N and 76° 42' 41.22" E), Kavarakundu (10° 52' 11.028" N and 76° 42' 59.76" E), Thakaramada(10° 52' 27.552" N and 76° 42' 44.316" E), Thaanikunnu (10° 51' 55.44" N and 76° 42' 0.108" E, 10° 51' 57.24" N and 76° 42' 5.04" E, 10° 52' 1.2" N and 76° 41' 57.48" E), Attippara (10° 52' 6.24" N and 76° 41' 53.16" E) Nakkamalakunnu 10° 52' 9.84" N and 76° 38' 56.04" E and Kochuthodu (10° 50' 41.28" N and 76° 42' 5.04" E and 10° 51' 58.32" N and 76° 42' 22.32" E).

1. Muchikadavu (10° 52' 5.16'' N and 76° 42' 41.22'' E)

Muchikadavu of Akamalavaram is located very near to Akamalavaram forest section office where forests are seen intermixed with private estates. The altitude of this area is around 79m. The area experienced small land slide washing away the surface soil along with the ground vegetation. The area showed uprooting of few trees along with mud and rocks reaching down the lane (Plate 1. Fig. a- f).

2. Kavarakundu (10° 52' 11.028'' N and 76° 42' 59.76'' E)

This spot is one of the beautiful areas in Akamalavaram section where there is a waterfall area which is rich in vegetation. Soil content in this area is low, with a rheophytic habitat and hence heavy rain resulted in washing away of vegetation on the rock surface. The average altitude of this place is 266. 09m. Uprooting of trees like *Grewia tiliifolia* is observed in this location (Plate 2. Fig. a-c).

3. Thakaramada(10° 52' 27.552'' N and 76° 42' 44.316'' E)

Near to Kavarakundu where average altitude comes near 270m is rich in vegetation comprising of moist deciduous and dry deciduous elements. Heavy downpour has resulted in the heavy outflow of rain water through the forest floor resulted in minor landslides in this spot uprooting several small trees and other herbaceous forms (Plate 2. Fig. d-f).

4. Thaanicunnu (10° 51' 55.44'' N and 76° 42' 0.108'' E, 10° 51' 57.24'' N and 76° 42' 5.04'' E, 10° 52' 1.2'' N and 76° 41' 57.48'' E)

This place is located near to Vettiyl estate, a Govt. owned Rubber – Arecanut- Sandel wood- *Xylia xylocarpa* plantation. The average altitude of this site is 167.3m. The heavy rain during monsoon have resulted in mudslides on the margins of this estate uprooting some rubber trees and other few forest trees. Kochuthodu, a river through the forest is flowing near to this spot (Plate 3. Fig.a-f; Plate 4 Fig. a-c).

5. Kochuthodu (10° 50' 41.28'' N and 76° 42' 5.04'' E) and (10° 51' 58.32'' N and 76° 42' 22.32'' E)

This is a small stream or river flowing through the Akamalavaram section along with other Rivers Mylaadumpuzha and Kallanpuzha. Mudslides near Vettiyl estate has resulted in the deposition of mud and silt in the Kochuthodu resulting in the reduction of waterflow through this river. It is also found that large rocks dumped during the flood are blocking the water flow (Plate 4. Fig. d-f).

6. Attippara (10° 52' 6.24" N and 76° 41' 53.16" E)

Attippara is located near to Thannikunnu with an average altitude of 252.24m experienced major landslide with washing away off top soil and uprooting of several trees. A great damage to the ground vegetation was recorded from here (Plate 5. Fig.a-c).

7. Nakkamalakunnu 10° 52' 9.84" N and 76° 38' 56.04" E

Located near go Akamalavaram is a biodiversity rich area which experienced major landslide during heavy monsoon leaving back only few survivors and new invasive taxa. The altitude of this region is 225.1m (Plate 5. Fig.d-f).

Effect of flood in Akamalavaram section

The destruction of largest patch of vegetation has been happened with surface vegetation of average 80 x 40 sq.m area being washed away, uprooting several tall trees like *Xylia xylocarpa* (Roxb.) Taub., *Grewia tiliifolia* Vahl, *Ficus racemosa* L., *Schleichera oleosa* (Lour.) Oken, *Holoptelea integrifolia* (Roxb.) Planch, and some smaller trees like *Chionanthus mala-elengi* (Dennst.) P. S. Green ssp. *mala-elengi*, Bull., *Helicteres isora* L., *Artocarpus hirsutus* Lam., *Dalbergia latifolia* Roxb. and *Ixora brachiata* Roxb. ex DC, and climbers like *Anamirta cocculus* (L.) Wight & Arn. and *Spatholobus parviflorus* (Roxb. ex DC.) O. Ktze.

Some minor mud slides occurred near Vettiyl estate, a govt. owned Rubber- Sandel wood – teak – *Xylia xylocarpa* plantation where heavy rain resulted in the uprooting of several rubber trees (*Hevea braziliensis* (Willd. ex A. Juss.) Muell.-Arg.) at the margins of the plantation. Along with that several other taxa are uprooted which include *Grewia tiliifolia* Vahl, *Macaranga peltata* (Roxb.) Muell.-Arg *Ficus racemosa* L., *Schleichera oleosa* (Lour.) Oken and *Holoptelea integrifolia* (Roxb.) Planch. Heavy flow of water has destroyed mostly the small herbaceous surface dwelling species which can be identified by comparing with the nearby vegetation. Herbaceous taxa such as *Baliospermum montanum* (Willd.) Muell.-Arg. in DC., *Biophytum reinwardtii* (Zucc.) Klotzsch. var. *reinwardtii*, *Acalypha paniculata* Miq., *Justicia simplex* D. Don, *Clerodendrum infortunatum* L., *Dipteracanthus prostratus* (Poir.) Nees, *Eranthemum capense* L. var. *capense*; Hook. f., *Eragrostis viscosa* (Retz.) Trin., *Hemigraphis crossandra* (Steud.) Bremek., *Brachiaria miliiformis* (J. Presl ex C. Presl) A. Chase, *Hemidesmus indicus* (L.) R. Br. in Ait.f. var. *indicus*; Hook. etc are found washed off in the heavy rains of August 2018.

Effects in Kochuthodu

Kochuthodu is the small stream flowing through Muchikadavu, Kavarakundu which got affected by the landslide at Muchikadavu and Kavarakundu. Here the water flowing capacity has become reduced due to the deposition of silt, mud and large boulders (rocks) during heavy rain. The riverine system is badly affected by the uprooting of *Homonoia riparia* Lour., and *Ficus hispida* L. There are also evidences of total uprooting of other riparian elements such as Poaceae and Cyperaceae members. After flood, lower river drainage in this riverine system has reduced the inflow of water into Malampuzha Dam.

Resilient taxa in Akamalavaram section

Thorough field explorations in the flood affected sites documented a list of survival taxa which includes *Ailanthus excelsa* Roxb., *Bambusa bambos* (L.) Voss, *Dillenia pentagyna* Roxb., *Ficus hispida* L. f., *Ficus microcarpa* L., *Calycopteris floribunda* Lam., *Mallotus philippensis* (Lam.) Muell.-Arg., *Spatholobus parviflorus* (Roxb. ex DC.) O. Ktze., *Streblus asper* Lour., *Tectona grandis* L., *Syzygium cumini* (L.) Skeels, (L.) Skeels, *Dalbergia latifolia* Roxb., *Terminalia paniculata* Roth, *Ficus racemosa* L., *Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guill. & Perr., *Xylia xylocarpa* (Roxb.) Taub., *Tectona grandis* L., *Sapindus trifoliatus* L. and *Dalbergia sissoo* Roxb.

Reasons for the Uprooting of taxa

Most of the uprooted taxa grew on the Forest floor with little soil cover and hence their root system will be spread on the rocky floor without going deep. Heavy rain resulted in the erosion of ground soil exposing the trees. This has increased the rate of uprooting and total run off of trees and shrubs. Since taxa with buttress root system is rare in this forest floor, erosion rate increased further.

Reasons for the Survival

Deep root system, Buttress roots, strong barks, the ability of taxa to grow as group like that in *Bambusa* and liana nature of some taxa *Spatholobus parviflorus* (Roxb. ex DC.) O. Ktze etc may be some of the reasons for their survival.

Table 1. summarizes the location based data of landslide along with data on tree uprooting.

Table 1. Location based data on effect of landslide on vegetation in Akamalavaram Section

Sl. No.	Location	Uprooted taxa
1	Muchikadavu	<i>Grewia tiliifolia</i> Vahl <i>Macaranga peltata</i> (Roxb.) Muell.-Arg <i>Ficus racemosa</i> L. <i>Schleichera oleosa</i> (Lour.) Oken <i>Holoptelea integrifolia</i> (Roxb.) Planch.
2	Kavarakundu	<i>Ficus racemosa</i> L. <i>Schleichera oleosa</i> (Lour.) Oken <i>Holoptelea integrifolia</i> (Roxb.) Planch. <i>Grewia tiliifolia</i> Vahl
3	Thakaramada	<i>Xylia xylocarpa</i> (Roxb.) Taub. <i>Grewia tiliifolia</i> Vahl <i>Schleichera oleosa</i> (Lour.) Oken <i>Spatholobus parviflorus</i> (Roxb. ex DC.) O. Ktze. <i>Ficus racemosa</i> L. <i>Chionanthus mala-elengi</i> (Dennst.) P. S. Green ssp. <i>mala-elengi</i> , Bull.
4	Kochuthodu	<i>Homonoia riparia</i> Lour. <i>Ficus hispida</i> L.
5	Thaanikunnu	<i>Grewia tiliifolia</i> Vahl <i>Schleichera oleosa</i> (Lour.) Oken <i>Hevea braziliensis</i> (Willd. ex A. Juss.
6	Attippara	<i>Grewia tiliifolia</i> Vahl <i>Schleichera oleosa</i> (Lour.) Oken <i>Dalbergia latifolia</i> Roxb.
7	Nakkamalakunnu	<i>Grewia tiliifolia</i> Vahl <i>Ficus racemosa</i> L. <i>Schleichera oleosa</i> (Lour.) Oken

Table 2. summarizes the details of taxa that could withstand the landslide and associated flood in Akamalavaram section of Walayar forest range

Table 2. Survivor taxa in landslide hit area in Akamalavaram section

Muchikadavu (10° 52' 5.16" N and 76° 42' 41.22" E)	Kavarakundu (10° 52' 11.028" N and 76° 42' 59.76" E)	Thakaramada(10° 52' 27.552" N and 76° 42' 44.316" E)	Thaanikunnu (10° 51' 55.44" N and 76° 42' 0.108" E, 10° 51' 57.24" N and 76° 42' 5.04" E, 10° 52' 1.2" N and 76° 41' 57.48" E)
<i>Acalypha paniculata</i> Miq.,	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	<i>Dalbergia latifolia</i> Roxb.,	<i>Xylia xylocarpa</i> (Roxb.) Taub.,
<i>Ailanthus excelsa</i> Roxb.,	<i>Dillenia pentagyna</i> Roxb.,	<i>Terminalia paniculata</i> Roth,	<i>Ficus racemosa</i> L.,
<i>Bambusa bambos</i> (L.) Voss	<i>Bambusa bambos</i> (L.) Voss	<i>Xylia xylocarpa</i> (Roxb.) Taub.,	<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,
<i>Dillenia pentagyna</i> Roxb.,	<i>Chionanthus mala-elengi</i> (Dennst.) P. S. Green ssp. <i>mala-elengi</i> , Bull.	<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,	<i>Bambusa bambos</i> (L.) Voss
<i>Ficus hispida</i> L. f.,	<i>Dalbergia latifolia</i> Roxb.,	<i>Bambusa bambos</i> (L.) Voss	<i>Chionanthus mala-elengi</i> (Dennst.) P. S. Green ssp. <i>mala-elengi</i> , Bull.
<i>Ficus microcarpa</i> L.	<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,		<i>Dalbergia latifolia</i> Roxb.,
<i>Calycopteris floribunda</i> Lam.,			<i>Terminalia paniculata</i> Roth,
<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.			
<i>Spatholobus parviflorus</i> (Roxb. ex DC.) O. Ktze.,			
<i>Streblus asper</i> Lour.,			
<i>Tectona grandis</i> L.			
<i>Xylia xylocarpa</i> (Roxb.) Taub.,			

Table 3. Survivor taxa in landslide hit area in Akamalavaram section (contd)

Attippara (10° 52' 6.24" N and 76° 41' 53.16" E)	Nakkamalakunnu (10° 52' 9.84" N and 76° 38' 56.04" E)	Kochuthodu (10° 50' 41.28" N and 76° 42' 5.04" E) and (10° 51' 58.32" N and 76° 42' 22.32" E)
<i>Anogeissus latifolia</i> (Roxb. ex DC.) Wall. ex Guill. & Perr.,	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	<i>Dalbergia latifolia</i> Roxb.,
<i>Bambusa bambos</i> (L.) Voss	<i>Anogeissus latifolia</i> (Roxb. ex DC.) Wall. ex Guill. & Perr.,	<i>Terminalia paniculata</i> Roth,
<i>Xylia xylocarpa</i> (Roxb.) Taub.,	<i>Spatholobus parviflorus</i> (Roxb. ex DC.) O. Ktze.,	<i>Xylia xylocarpa</i> (Roxb.) Taub.,
<i>Terminalia paniculata</i> Roth,	<i>Zingiber nimmonii</i> Dalz.	<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,
<i>Tectona grandis</i> L.	<i>Sapindus trifoliatus</i> L.,	<i>Bambusa bambos</i> (L.) Voss
	<i>Dalbergia sissoo</i> Roxb.,	<i>Dillenia pentagyna</i> Roxb.,
	<i>Tectona grandis</i> L.	<i>Spatholobus parviflorus</i> (Roxb. ex DC.) O. Ktze.
	<i>Briedelia retusa</i> (L.) A. Juss.	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.
		<i>Anamirta cocculus</i> (L.) Wight & Arn.
		<i>Artocarpus hirsutus</i> Lam.
		<i>Ixora brachiata</i> Roxb. ex DC.

Table 4. Primary colonizers in landslide hit areas in Akamalavaram Section

Muchikadavu (10° 52' 5.16" N and 76° 42' 41.22" E)	Kavarakundu (10° 52' 11.028" N and 76° 42' 59.76" E)	Thakaramada (10° 52' 27.552" N and 76° 42' 44.316" E)	Thaanikunnu (10° 51' 55.44" N and 76° 42' 0.108" E, 10° 51' 57.24" N and 76° 42' 5.04" E, 10° 52' 1.2" N and 76° 41' 57.48" E)
<i>Naravelia zeylanica</i> (L.) DC.,	<i>Eranthemum capense</i> L., var. capense; Hook. f.	<i>Desmodium triflorum</i> (L.) DC.	<i>Rhinacanthus nasutus</i> (L.) Kurz
<i>Baliospermum montanum</i> (Willd.) Muell.-Arg. in DC	<i>Rhinacanthus nasutus</i> (L.) Kurz	<i>Pseudarthria viscida</i> (L.) Wight & Arn.	<i>Naravelia zeylanica</i> (L.) DC.,
<i>Eranthemum capense</i> L., var. capense; Hook. f.	<i>Naravelia zeylanica</i> (L.) DC.,	<i>Leucas aspera</i> (Willd.)	<i>Spilanthes radicans</i> Jacq., Co
<i>Rhinacanthus nasutus</i> (L.) Kurz		<i>Alternanthera bettzickiana</i> (Regel) Voss	<i>Alternanthera bettzickiana</i> (Regel) Voss
<i>Oplismenus burmannii</i> (Retz.) P. Beauv.,		<i>Naravelia zeylanica</i> (L.) DC.,	<i>Arundinella mesophylla</i> Nees ex Steud.
<i>Arundinella mesophylla</i> Nees ex Steud.		<i>Spilanthes radicans</i> Jacq., Co <i>Arundinella mesophylla</i> Nees ex Steud.	
Attippara (10° 52' 6.24" N and 76° 41' 53.16" E)	Nakkamalakunnu (10° 52' 9.84" N and 76° 38' 56.04" E)		Kochuthodu (10° 50' 41.28" N and 76° 42' 5.04" E) and (10° 51' 58.32" N and 76° 42' 22.32" E)
<i>Baliospermum montanum</i> (Willd.) Muell.-Arg. in DC	<i>Acalypha paniculata</i> Miq.,		<i>Naravelia zeylanica</i> (L.) DC.,
<i>Clerodendrum infortunatum</i> L.,	<i>Baliospermum montanum</i> (Willd.) Muell.-Arg. in DC		<i>Baliospermum montanum</i> (Willd.) Muell.-Arg. in DC
<i>Rhinacanthus nasutus</i> (L.) Kurz	<i>Rungia pectinata</i> (L.) Nees		<i>Eranthemum capense</i> L., var. capense; Hook. f.
<i>Rungia pectinata</i> (L.) Nees	<i>Clerodendrum infortunatum</i> L.,		<i>Rhinacanthus nasutus</i> (L.) Kurz
<i>Digitaria ciliaris</i> (Retz.) Koeler,	<i>Pseudarthria viscida</i> (L.) Wight & Arn.,		<i>Oplismenus burmannii</i> (Retz.) P. Beauv.,
<i>Oplismenus burmannii</i> (Retz.) P. Beauv.,	<i>Acalypha paniculata</i> Miq.,		<i>Arundinella mesophylla</i> Nees ex Steud.

Table 5. Invaders in landslide hit areas in Akamalavaram Section

Muchikadavu (10° 52' 5.16" N and 76° 42' 41.22" E)	Kavarakundu (10° 52' 11.028" N and 76° 42' 59.76" E)	Thakaramada(10° 52' 27.552" N and 76° 42' 44.316" E)	Thaanikunnu (10° 51' 55.44" N and 76° 42' 0.108" E, 10° 51' 57.24" N and 76° 42' 5.04" E, 10° 52' 1.2" N and 76° 41' 57.48" E)
<i>Mimosa pudica</i> L.	<i>Clerodendrum infortunatum</i> L.	<i>Lantana camara</i> L.	<i>Mikania micrantha</i> Kunth
	<i>Mimosa pudica</i> L.	<i>Centrosema molle</i> Benth.	<i>Lantana camara</i> L.
<i>Mikania micrantha</i> Kunth	<i>Mikania micrantha</i> Kunth	<i>Chromolaena odorata</i> (L.) King & Robins.	<i>Mimosa pudica</i> L.
<i>Chromolaena odorata</i> (L.) King & Robins.	<i>Chromolaena odorata</i> (L.) King & Robins.	<i>Clerodendrum infortunatum</i> L.	<i>Chromolaena odorata</i> (L.) King & Robins.
<i>Lantana camara</i> L.	<i>Lantana camara</i> L.	<i>Ichnocarpus frutescens</i> (L.) R. Br	<i>Ageratum conyzoides</i> L.
		<i>Mimosa pudica</i> L.	

Invaders in landslide hit areas in Akamalavaram Section (contd.)

Attippara (10° 52' 6.24" N and 76° 41' 53.16" E)	Nakkamalakunnu (10° 52' 9.84" N and 76° 38' 56.04" E)	Kochuthodu (10° 50' 41.28" N and 76° 42' 5.04" E) and (10° 51' 58.32" N and 76° 42' 22.32" E)
<i>Hyptis suaveolens</i> (L.) Poit.,	<i>Mikania micrantha</i> Kunth	<i>Lantana camara</i> L.,
<i>Chromolaena odorata</i> (L.) King & Robins.,,	<i>Blumea laevis</i> (Lour.) Merr.,	<i>Centrosema molle</i> Benth.,
<i>Mikania micrantha</i> Kunth		<i>Chromolaena odorata</i> (L.) King & Robins.,,
		<i>Clerodendrum infortunatum</i> L.,
		<i>Ichnocarpus frutescens</i> (L.) R. Br
		<i>Mimosa pudica</i> L.,

III.1.2. Kottekkad Section

Parachathi (Plates 6-12)

The Kottekkad forest section of Walayar forest range was severely affected by the flood and subsequent landslides. Parachathi and Aduppukootimala witnessed the huge loss of top soil along with the destruction of natural vegetation. Parachathi is located between Malampuzha and Kava in the catchment site of Malampuzha Dam. Landslides originated from top of the hill created blockade in the transport via road. Water level was increased unusually, submerging households. There were five locations beginning from 10° 50'37.32"N and 76° 43' 40.8" E up to 10° 50' 38.76"N and 76° 43' 51.96"E hit by the landslides in Parachathi hills. These locations were having an elevation of 30 m, 147m, 155.3m, 164.7m and 144.8m respectively from the sea level. Plantations of *Cocos nucifera*, *Musa paradisiaca* and *Hevea brasiliensis* at the lower stretches had severe loss. *Wrightia tinctoria* is one of the prominent species uprooted alongside others. Other major tree species uprooted in this area are *Ficus racemosa* L., *Grewia tiliifolia* Vahl, *Hevea brasiliensis* (Willd. ex A. Juss.) Muell.-Arg., *Ficus hispida* L. f., and *Schleichera oleosa* (Lour.) Oken. The lower agricultural lands were destructed by the heavy deposition of sand and one of the streams which feeded Malampuzha Dam got disappeared by sand filling.

Currently this area is under quick replenishment by the pioneer species like *Lindernia viscosa* (Hornem.) Merr., *Glinus oppositifolius* (L.) A. DC., *Amaranthus viridis* L., *Eragrostis tenella* (L.) P. Beauv. ex Roem. & Schult., *Anisochilus carnosus* (L. f.) Wall. ex Benth. etc...

Aduppukootimala (Plate 13. Fig.a-f)

The other location hit by the flood in the Kottekkad section is Aduppukootimala. This place is also had four locations affected by the landslides from 10° 49' 39"N and 76° 44' 16.08"E to 10° 50.8.16"N and 76°44' 33.36"E. The elevations of these places ranges from 154.1m to 343m from sea level. The area witnessed tree fall in higher magnitude. The uprooted plants include *Bauhinia racemosa* Lam., *Holoptelea integrifolia* (Roxb.) Planch., *Grewia tiliifolia* Vahl, *Bombax ceiba* L., *Syzygium cumini* (L.) Skeels etc... The range had plenty of survivor species including *Terminalia paniculata* Roth, *Miliusa tomentosa* (Roxb.) Finet & Gagnep., *Terminalia chebula* Retz., *Holarrhena pubescens* (Buch.-Ham.) Wall. ex G. Don, *Harpullia arborea* (Blanco) Radlk., *Tabernaemontana alternifolia* L., *Ixora brachiata* Roxb. ex DC., etc... The rapid spread of pioneer species help the region from severe loss of vegetation. These plants include *Arundinella mesophylla* Nees ex Steud., *Dicliptera paniculata* (Forssk.) I. Darbysh.,

Dicliptera foetida (Forssk.) Blatt., *Haplanthodes neilgherryensis* (Wight) Majumdar, *Eranthemum capense* L., *Phaulopsis imbricata* (Forssk.) Sweet., *Argyreia elliptica* (Roth) Choisy etc. In addition to these, several invaders like *Mikania micrantha* Kunth, *Hyptis suaveolens* (L.) Poit., *Chromolaena odorata* (L.) King & Robins., *Lantana camara* L. and *Ageratum conyzoides* L. are also spreading in this area.

III.1.3. Pudussery South Section (Plates 14-20)

Pudussery South section is under Walayar forest range which covers a total area of about 5.90 Sq. Km. No forest area in this section is reserve forest but is vested. Some of the forest area in this section was badly affected by the heavy rain during the month of August 2018. Certain areas in this section experienced minor flood-caused landslides and mud slides which includes Ayyappanmala (10° 49' 16.896" N and 76° 46' 28.8948" E), Velancherry (10° 49' 37.56" N and 76° 45' 55.8" E) and Anakundu (10° 49' 52.32" N and 76° 46' 13.08" E).

1. Ayyappanmala (10° 49' 16.896" N and 76° 46' 28.8948" E)

Ayyappanmala of Pudussery South section is located near to Aduppukootimala. The altitude of this area is above 500 m. The mountain got this name due to the small temple of lord Ayyappa at the top of this mountain. Yearly ritual and worship occurs during the month of December. The area experienced severe landslide washing away the ground vegetation and few trees forming a channel of mud and rocks reaching down.

2. Velanchery

Velanchery is located 2km away from Ayyappanmala. Here B tract railway line passes and is one of the major elephant corridors in Walayar Forest range.

3. Anakundu (10° 49' 52.32" N and 76° 46' 13.08" E)

Anakundu is located near to Velanchery. The place gets this name by the old construction of “Ana” or check dam using rocks and then called “surka” by the Britishers. This formed the main source of water to Korayar river and near by ponds like Valiyaeri which is the life saving source of water for wild animals and humans. Heavy rain has resulted in the heavy outflow of rain water through the forest floor resulted in and slides totally destructing this “Ana”.

Effects of flood in Pudussery South section

The largest patch of destruction has happened with surface vegetation of average 60 x 30 sq.m area being washed away, uprooting several tall trees like *Bombax ceiba* L, *Careya arborea* Roxb., *Xylia xylocarpa* (Roxb.) Taub, *Terminalia paniculata* Roth, *Grewia tiliifolia* Vahl,

Erythrina variegata L. *Ficus racemosa* L., *Schleichera oleosa* (Lour.) Oken and *Alangium salviifolium* (L. f.) Wang. in Engl ssp. *salviifolium* Gamble. Heavy rain caused massive landslides which completely washed out the ground flora especially the herbs such as *Leucas chinensis* (Retz.) R. Br, *Andrographis elongata* (Vahl) Anders., *Baliospermum montanum* (Willd.) Muell.-Arg. in DC., *Clerodendrum infortunatum* L., *Dipteracanthus prostratus* (Poir.) Nees, *Eranthemum capense* L. var. *capense*; Hook. f., *Eragrostis viscosa* (Retz.) Trin., *Brachiaria miliiformis* (J. Presl ex C. Presl) A. Chase, *Hemidesmus indicus* (L.) R. Br. in Ait.f. var. *indicus*; Hook. etc

Effects in Ayyappanmala

Ayyappanmala landslide caused heavy destruction resulted in washing off the forest soil along with large rocks. Sand and silt from the forest got desposited on the stream down the hill. Excess soil and sand got spread on the nearby private land making it unsuitable for agriculture.

Sand and silt deposition favoured survival and fast spreading of certain taxa such as *Arundo donax* L., *Vitex negundo* L., *Chromolaena odorata* (L.) King & Robins. and *Lantana camara* L. Deep tuberous root system of *Arundo donax* L. will prevent further soil erosion in the area. Primary colonisers of the affected area include *Mollugo oppositifolia* L., *Eragrostis riparia* (Willd.) Nees, *Torenia hirsuta* Willd, *Leucas chinensis* (Retz.) R. Br., *Solanum torvum* Sw., *Crotalaria spectabilis* Roth, *Trianthema portulacastrum* L. etc.

Falling of large trees have opened up the canopy resulting in the fast drying of forest floor. There is a hike in the atmospheric temperature which resulted in the wilting of these primary colonisers too. Landslide created a new channel for the flow of rain water through hill.

Reasons for the Uprooting

All the taxa which fell in landslide grew in little soil supported by large rocks. Heavy rain resulted in the erosion of ground soil exposing the trees on rocks. Poor root system has paved the way for their uprooting. Lack of buttress root system is also one of the reason for uprooting.

Reasons for the Survival

Some climber taxa such as *Spatholobus parviflorus* (Roxb. ex DC.) O. Ktze, and other trees such as *Syzygium cumini* (L.) Skeels, *Dalbergia latifolia* Roxb. etc are some of the survival taxa and their strong root system and higher soil content in those forest floor, might have been the cause for their survival.

**Table 6. Location based data on effect of landslide on vegetation in Pudussery south
Section**

Sl. No.	Location	Uprooted taxa
1	Ayyappanmala (10° 49' 16.896" N and 76° 46' 28.8948" E)	<i>Grewia tiliifolia</i> Vahl <i>Macaranga peltata</i> (Roxb.) Muell.-Arg <i>Ficus racemosa</i> L. <i>Bombax ceiba</i> L. <i>Careya arborea</i> Roxb. <i>Xylia xylocarpa</i> (Roxb.) Taub <i>Terminalia paniculata</i> Roth <i>Grewia tiliifolia</i> Vahl <i>Erythrina variegata</i> L.
2	Velanchery (10° 49' 37.56" N and 76° 45' 55.8" E)	<i>Ficus racemosa</i> L. <i>Xylia xylocarpa</i> (Roxb.) Taub <i>Spatholobus parviflorus</i> (Roxb. ex DC.) O. Ktze. <i>Grewia tiliifolia</i> Vahl <i>Bombax ceiba</i> L.
3	Anakundu (10° 49' 52.32" N and 76° 46' 13.08" E)	<i>Grewia tiliifolia</i> Vahl <i>Ficus racemosa</i> L. <i>Calycopteris floribunda</i> Lam., <i>Alangium salviifolium</i> (L. f.) Wang. <i>Strychnos potatorum</i> L.

Table 7. Survivor taxa in landslide hit area in Pudussery South section

Ayyappanmala (10° 49' 16.896'' N and 76° 46' 28.8948'' E)	Velanchery (10° 49' 37.56'' N and 76° 45' 55.8'' E)	Anakundu (10° 49' 52.32'' N and 76° 46' 13.08'' E)
<i>Xylia xylocarpa</i> (Roxb.) Taub.,	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	<i>Dalbergia latifolia</i> Roxb.,
<i>Spatholobus parviflorus</i> (Roxb. ex DC.) O. Ktze.,	<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,	<i>Terminalia paniculata</i> Roth,
<i>Dalbergia latifolia</i> Roxb.,	<i>Calycopteris floribunda</i> Lam.,	<i>Xylia xylocarpa</i> (Roxb.) Taub.,
<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,	<i>Terminalia bellirica</i> (Gaertn.) Roxb.,	<i>Syzygium cumini</i> (L.) Skeels, (L.) Skeels,
<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	<i>Grewia tiliifolia</i> Vahl,	<i>Bambusa bambos</i> (L.) Voss
<i>Streblus asper</i> Lour.,	<i>Acacia catechu</i> (L.f.) Willd.,	<i>Calycopteris floribunda</i> Lam.,
	<i>Alangium salviifolium</i> (L. f.) Wang.	<i>Vitex altissima</i> L.
		<i>Terminalia bellirica</i> (Gaertn.) Roxb.,
		<i>Grewia tiliifolia</i> Vahl,
		<i>Acacia catechu</i> (L.f.) Willd.,
		<i>Alangium salviifolium</i> (L. f.) Wang.

Post Landslide modifications

Sand and silt were dumped to the agricultural land and nearby water bodies in Ayyappanmala which further reduced the soil fertility and water holding capacity. In Velanchery, soil deposition and fallen trees reached even the B track of railway line which partially blocked the rail service for a day. The soil was then removed with the help of machines and manpower. In Anakundu, the destruction of “Ana” resulted in the dumping of sand and silt to the nearby lowlands and agricultural lands which totally destroyed the whole agriculture sector in this area. It is also observed that fast evaporation of the ground water leading to the accelerated drying of the forest floor than their normal drying rate. This will lead to the total dryness of the forest which will lead to increased forest temperature badly affecting the survival of both flora and fauna. Also there is a high chance of forest fire in these dry areas.

Table 8. Primary colonizers in landslide hit areas in Pudussery South Section

Ayyappanmala (10° 49' 16.896" N and 76° 46' 28.8948" E)	Velanchery (10° 49' 37.56" N and 76° 45' 55.8" E)	Anakundu (10° 49' 52.32" N and 76° 46' 13.08" E)
<i>Ageratum houstonianum</i> Mill.,	<i>Vitex negundo</i> L.	<i>Pentanema indicum</i> (L.) Ling,
<i>Digitaria ciliaris</i> (Retz.) Koeler,	<i>Arundo donax</i> L.,	<i>Mitracarpus hirtus</i> (L.) DC.
<i>Arundo donax</i> L.,	<i>Ageratum houstonianum</i> Mill.,	<i>Mollugo oppositifolia</i> L.
<i>Mitracarpus hirtus</i> (L.) DC.	<i>Mollugo oppositifolia</i> L.	<i>Calycopteris floribunda</i> Lam.,
<i>Achyranthes aspera</i> L.,	<i>Digitaria ciliaris</i> (Retz.) Koeler,	<i>Ageratum houstonianum</i> Mill.,
<i>Digitaria ciliaris</i> (Retz.) Koeler,	<i>Lindernia antipoda</i> (L.) Alston in Trimen	<i>Digitaria ciliaris</i> (Retz.) Koeler,
<i>Mollugo oppositifolia</i> L.	<i>Eragrostis unioloides</i> (Retz.) Nees ex Steud.	<i>Arundo donax</i> L.,
<i>Acacia catechu</i> (L.f.) Willd.,	<i>Desmodium pulchellum</i> (L.) Benth.	<i>Acacia catechu</i> (L.f.) Willd.,
<i>Vitex negundo</i> L.		<i>Achyranthes aspera</i> L.,
		<i>Desmodium pulchellum</i> (L.) Benth.
		<i>Orthosiphon thymiflorus</i> (Roth) Sleesen,

Table 9. Invaders in landslide hit areas in Pudussery South Section

Ayyappanmala (10° 49' 16.896" N and 76° 46' 28.8948" E)	Velanchery (10° 49' 37.56" N and 76° 45' 55.8" E)	Anakundu (10° 49' 52.32" N and 76° 46' 13.08" E)
<i>Mimosa pudica</i> L.	<i>Mimosa pudica</i> L.	<i>Mikania micrantha</i> Kunth
<i>Mikania micrantha</i> Kunth	<i>Mikania micrantha</i> Kunth	<i>Ageratum conyzoides</i> L.
<i>Chromolaena odorata</i> (L.) King & Robins.	<i>Hyptis suaveolens</i> (L.) Poit.	
<i>Lantana camara</i> L.	<i>Lantana camara</i> L.	
<i>Ageratum conyzoides</i> L.		

III. 2. Post flood effects and landslides in Olavakkode Forest range

Olavakkode Forest range

The major reserve forest in this range is Dhoni hills, which experienced mini mudslides and major landslide in ecotourism site. This caused heavy loss in forest roads and which ultimately affected the tourism in the range. The terrain and the vegetation are relatively unscathed especially in the lower elevations. But at higher altitudes several small denuded areas are visible from afar where it used to be completely covered with lush green canopy. Natural animal shelters and movement tracks have been heavily damaged and the habitation of large wild animals and their movements have been disrupted.

III.2.1. Dhoni Section (Plate 21. Fig.a-f)

Dhoni section of Olavakkode forest division had flood-caused landslides in a few area within the Dhoni Reserve Forest. The largest patch of destruction has happened at 10° 51' 56.484" N 76° 37' 15.708" E with surface vegetation of 100 x 40 sq.m area being washed away, uprooting several tall trees like *Terminalia bellerica*, *Xylia xylocarpa*, *Grewia tiliifolia*, *Swietenia mahagoni* and smaller trees like *Sapindus emarginatus*, *Dalbergia latifolia*, *Bridelia retusa* and *Ixora brachiata*. Destruction of surface vegetation has also taken place at three other locations with approximately 15 x 5 sq. m area being washed away. In these areas in addition to the trees mentioned above *Macaranga peltata*, *Pterocymbium tinctorium* var. *javanicum*, *Ficus racemosa*, *Holigarna arnottiana*, *Anacardium occidentale*, and smaller trees like *Hopea ponga*, *Diospyrus ebenum*, *Plectronia parvifolia* and herbs like *Barleria*, *Biophytum reinwardtii* etc. have been uprooted. Most of the uprooted plants have also been found to survive the flood water onslaught in certain locations, making it difficult to identify and categorise the species as flood resistant or prone to easy uprooting forms. The uprooting in most cases seems to be due to large boulders being washed down and not entirely due to water flow alone. Superficial flow of water has destroyed mostly the small herbaceous surface dwelling species. Uprooting of large trees have opened up the canopy increasing light penetration to the under storey that was sheltered so far. This has allowed several sciophytic forms to thrive better than they used to in the same locations. The soil structure of the flood affected region has undergone a drastic change with a lot of silt being washed down and deposited over what used to be litter-filled humus rich damp forest floor.

Resilient taxa in landslide hit areas in Dhoni hills

Trees like *Ailanthus excelsa*, *Terminalia bellerica*, *Xylia xylocarpa*, *Sweetenia mahagoni*, *Pterocymbium tinctorium* and *Tectona grandis* seems to have withstood the onslaught of heavy rains and flooding waters. These trees most likely would have been able to establish a deep and strong root system, both due to its inherent ability and also to the soil structure of the substratum which allows for strong anchorage. The elevation gradient could also be a factor in allowing trees to withstand the landslide effect. Table 2. summarizes the details of taxa that could withstand the landslide and associated flood in Dhoni section of Olavakkode forest range.

Table 10. Location based data on effect of landslide on vegetation in Dhoni Reserve forest

Sl. No.	Location	Area hit	Uprooted taxa
1	10°51'58" N 76°37'11" E	15 x 5 sq.m	<i>Ailanthus excelsa</i> <i>Anacardium occidentale</i> <i>Holigarna arnottiana</i> <i>Pterocymbium tinctorium</i> var. <i>javanicum</i> <i>Sapindus emarginatus</i>
2	10°51'55" N 76°37'9" E	12 x 5 sq. m	<i>Ailanthus excelsa</i> <i>Terminaliabellerica</i> <i>Xylia xylocarpa</i>
3	10°52'55" N 76°37'6" E	15 x 7 sq. m	<i>Barleria</i> sp. <i>Biophytum reinwardtii</i> <i>Caryota urens</i> <i>Diospyros ebenum</i> <i>Ficus racemosa</i> <i>Hopea ponga</i> <i>Macaranga peltata</i> <i>Plectronia parviflorus</i> <i>Swietenia mahagoni</i>
4	10° 51' 56.484" N 76° 37' 15.708" E	100 x 40 sq.m	<i>Bridelia retusa</i> <i>Dalbergia latifolia</i> <i>Grewia tiliifolia</i> <i>Ixora brachiata</i> <i>Sapindus emarginatus</i> <i>Swetenia mahagoni</i> <i>Terminalia bellerica</i> <i>Xylia xylocarpa</i>

Table 11. Survivors in landslide hit area in Dhoni Reserve Forest

10°51'58" N 76°37'11" E	10°51'55" N 76°37'9" E	10°52'55" N 76°37'6" E	10° 51' 56.484" N 76° 37' 15.708" E
<i>Acalypha paniculate</i>	<i>Ailanthus excels</i>	<i>Adiantum lanceolatum</i>	<i>Abutilon persicum</i>
<i>Ageratum</i>	<i>Albizzia</i>	<i>Ailanthus excelsa</i>	<i>Aerides maculosa</i>
<i>Albizia saman</i>	<i>Allmania nodiflora</i>	<i>Amphineuron</i>	<i>Bridelia retusa</i>
<i>Chassalia curviflora</i>	<i>Artocarpus heterophyllus</i>	<i>Barleria montana</i>	<i>Caesalpinia bonduc</i>
<i>Curculigo orchioides</i>	<i>Canthium rheedei</i>	<i>Bolbyitis cordata</i>	<i>Ceiba pentandra</i>
<i>Delonix regia</i>	<i>Chassalia curviflora</i>	<i>Costus speciosa</i>	<i>Cissampelos pariera</i>
<i>Ficus sp</i>	<i>Cipadessa baccifera</i>	<i>Crotalaria heyneana</i>	<i>Crotalaria heyneana</i>
<i>Glycosmis pentaphylla</i>	<i>Curculigo orchioides</i>	<i>Cyclea peltata</i>	<i>Curcuma ecalcarata</i>
<i>Grewia tiliifolia</i>	<i>Cyanotis axillaris</i>	<i>Elephantopus scaber</i>	<i>Hibiscus surattensis</i>
<i>Hibiscus lobatus</i>	<i>Ficus racemose</i>	<i>Eranthemum capens</i>	<i>Macaranga peltata</i>
<i>Ixora brachiata</i>	<i>Geophila racemose</i>	<i>Ficus racemosa</i>	<i>Naravelia zeylanica</i>
<i>Laportea interrupta</i>	<i>Hemidesmis indicus</i>	<i>Globba sessiliflora</i>	<i>Ophiorrhiza mungos</i>
<i>Lepidogathis incurve</i>	<i>Ixora brachiata</i>	<i>Hibiscus sabdarifolia</i>	<i>Pouzolzia zeylanica</i>
<i>Merremia vitifolia</i>	<i>Lagerstroemia speciosa</i>	<i>Leea indica</i>	<i>Pterocymbium tinctorium</i>
<i>Naringi crenulata</i>	<i>Linociera malabarica</i>	<i>Lepidagathis incurva</i>	<i>Sapindus trifoliatus</i>
<i>Pouzolzia zeylanica</i>	<i>Mallotus philippensis</i>	<i>Macaranga petlata</i>	<i>Swietenia mahagoni</i>
<i>Piper longum</i>	<i>Pterocarpus marsupium</i>	<i>Pseudarthria viscida</i>	<i>Xylia xylocarpa</i>
<i>Pothos scandens</i>	<i>Pterocymbium tinctorium</i> var. javanicum	<i>Pteris</i> sp.	
<i>Pupalia lappacea</i>	<i>Pupalia lappacea</i>	<i>Pterocarpus marsupium</i>	
<i>Sida acuta</i>	<i>Rhynchoglossum notonianum</i>	<i>Putranjiva roxburghiana</i>	
<i>Sida cordifolia</i>	<i>Swietenia mahagoni</i>	<i>Schleichera oleosa</i>	
<i>Strychnos nux-vomica</i>	<i>Tectona grandis</i>	<i>Selaginella</i> sp.	
<i>Synedrella nodiflora</i>	<i>Terminalia bellerica</i>	<i>Sterculia urens</i>	
<i>Tectona grandis</i>	<i>Xylia xylocarpa</i>	<i>Swietenia mahagoni</i>	
<i>Truimfetta</i>		<i>Tecteria caudinata</i>	
<i>rhomboidea</i>		<i>Zingiber cernuum</i>	

Table 12. Primary colonizers in landslide hit areas in Dhoni hills

10°51'58" N 76°37'11" E	10°51'55" N 76°37'9" E	10°52'55" N 76°37'6" E	10° 51' 56.484" N 76° 37' 15.708" E
<i>Acalypha paniculata</i> Miq.,	<i>Allmania nodiflora</i> (L.) R. Br. ex Wight	<i>Costus speciosus</i> (Koenig) J.E. Smith,	<i>Abutilon indicum</i> (L.) Sweet,
<i>Ageratum conyzoides</i> L.,	<i>Chassalia curviflora</i> (Wall. ex Kurz) Thw. var. <i>ophioxyloides</i> (Wall.) Deb & Krishna,	<i>Crotalaria heyneana</i> Graham ex Wight & Arn.,	<i>Aerides maculosa</i> Lindl.,
<i>Chassalia curviflora</i> (Wall. ex Kurz) Thw. var. <i>ophioxyloides</i> (Wall.) Deb & Krishna,	<i>Chionanthus mala-elengi</i> (Dennst.) P. S. Green ssp. <i>mala-elengi</i> ,	<i>Cyclea peltata</i> (Lam.) Hook. f. & Thoms.,	<i>Cissampelos pareira</i> L. var. <i>hirsuta</i> (Ham. ex DC.) Forman,
<i>Curculigo orchioides</i> Gaertn.,	<i>Geophila repens</i> (L.) Johnst.,	<i>Elephantopus scaber</i> L.,	<i>Hibiscus surattensis</i> L.,
<i>Glycosmis pentaphylla</i> (Retz.) DC.,	<i>Hemidesmus indicus</i> (L.) R. Br.	<i>Eranthemum capense</i> L.,	<i>Naravelia zeylanica</i> (L.) DC.,
<i>Hibiscus lobatus</i> (Murr.) O. Ktze.,	<i>Rhynchoglossum notonianum</i> (Wall.) Burt,	<i>Globba sessiliflora</i> Sim.,	<i>Pouzolzia zeylanica</i> (L.)
<i>Laportea interrupta</i> (L.)	<i>Curculigo orchioides</i> Gaertn.,	<i>Hibiscus sabdariffa</i> L.,	
<i>Lepidagathis incurva</i> Buch.-Ham. ex D.Don,	<i>Cyanotis papilionacea</i> (Burm. f.) Schult. f.,	<i>Leea indica</i> (Burm. f.) Merr.,	
<i>Naringi crenulata</i> (Roxb.)		<i>Lepidagathis incurva</i> Buch.-Ham. ex D.Don,	
<i>Pouzolzia zeylanica</i> (L.)		<i>Pseudarthria viscida</i> (L.) Wight & Arn.,	
<i>Pupalia lappacea</i> (L.)			
<i>Sida acuta</i> Burm. f.			
<i>Sida cordifolia</i> L.,			
<i>Synedrella nodiflora</i> (L.) Gaertn.,			
<i>Triumfetta rhomboidea</i> Jacq.,			

III.2.2. Elival section (Plate 22. Fig.a-f)

Elival section of Olavakkode Forest division experienced landslides due to incessant rains in seven locations, the largest over an area of 1500 sq. m, though diversity loss in this area was limited as the region had a teak plantation. Two smaller areas of 50 sq. m and 10 sq. m area in the higher altitudes of 1200 -1300 feet caused loss of biodiversity as the area had natural semi evergreen forest vegetation. Most pronounced effect of landslides is the uprooting of trees like *Sapindus trifoliatus*, *Strychnos nux-vomica*, *Macaranga peltata*, and *Lagerstroemia speciosa* apart from *Tectona grandis* in the plantation site (Table 13).

The taxa that seem to have withstood the onslaught of the torrential rain and mudslide most effectively are *Mallotus philippensis* (Lam.) Muell.-Arg., *Sapindus emarginatus* Vahl, and *Cipadessa baccifera* (Roth) Miq.(Table 2). The herbaceous taxa that have survived the landslides are *Mitracarpus hirtus* (L.) DC., *Acmella paniculata* (Wall. ex DC.) R.K. Jansen, *Oplismenus burmannii* (Retz.) P. Beauv. and *Rungia pectinata* (L.) Nees. The number of survivor species is relatively low because these trees are seen in high numbers forming a dominant component of the vegetation there.

Several locations where the surface has seen much upheaval resulting in the surface being covered with new soil layers, show the presence of taxa that are relatively new colonizers to the area. Such taxa are *Cipadessa baccifera*, *Mallotus philippensis*, *Sapindus emarginatus* and *Panicum notatum* (Table 15).

Table 13. Location based data on effect of landslide on vegetation in Elival section

Sl. No.	Location	Area hit	Uprooted taxa
1	10° 52' 20.9892" N 76° 38' 13.884" E	20 x 10 sq. m	<i>Sapindus trifoliatus</i>
2	10° 52' 34.707" N 76° 38' 4.466" E	5 x 6 sq. m	<i>Strychnos nux-vomica</i>
3	10° 52' 36.336" N 76° 38' 22.2" E	10 x 6 sq. m	<i>Macaranga peltate</i>
4	10° 52' 41.088" N 76° 37' 59.16" E	5 x 6 sq. m	<i>Lagerstroemia speciose</i>
5	10° 52' 43.348" N 76° 38' 0.659" E	6 x 6 sq. m	<i>Macaranga peltate</i>
6	10° 52' 45.077" N 76° 38' 1.346" E	10 x 5 sq.m	<i>Macaranga peltate</i>
7	10° 52' 27.444" N 76° 38' 26.196" E	30 x 500 sq.m	<i>Tectona grandis</i>

Table. 14. Survivor taxa in landslide hit area in Elival Section

10° 52' 20.9892'' N 76° 38' 13.884'' E	10° 82' 34.707'' N 76° 38' 4.466'' E	10° 52' 36.336'' N 76° 38' 22.2'' E	10° 52' 41.088'' N 76° 37' 59.16'' E	10° 52' 43.348'' N 76° 38' 0.659'' E	10° 52' 45.077'' N 76° 38' 1.346'' E	10° 52' 27.444'' N 76° 38' 26.196'' E
Ailanthus excelsa Roxb.,	Carica papaya L.,	Calamus rotang L.,	Ficus microcarpa L. f.,	Abutilon indicum (L.) Sweet,	Acacia caesia (L.) Willd.	Cipadessa baccifera (Roth) Miq.
Bombax ceiba L.,	Caryota urens L.,	Dalbergia latifolia Roxb.,	Lagerstroemia parviflora Roxb.,	Ailanthus excelsa Roxb.,	Acemella paniculata (Wall. ex DC.) R.K. Jansen,	Mitracarpus hirtus (L.) DC.
Cipadessa baccifera (Roth) Miq.	Cipadessa baccifera (Roth) Miq.	Mallotus philippensis (Lam.) Muell.-Arg.,	Mallotus philippensis (Lam.) Muell.-Arg.,	Streblus asper Lour.,	Alstonia scholaris (L.) R. Br.,	Pongamia pinnata (L.) Pierre,
Garuga pinnata Roxb.,	Ixora brachiata Roxb. ex DC.	Sapindus emarginatus Vahl	Zingiber nimmonii Dalz.	Terminalia paniculata Roth,	Lagerstroemia parviflora Roxb.,	Sapindus emarginatus Vahl
Macaranga peltata (Roxb.) Muell.-Arg.	Macaranga peltata (Roxb.) Muell.-Arg.	Trewia nudiflora L.,			Mallotus philippensis (Lam.) Muell.-Arg.,	
Naringi crenulata (Roxb.)	Mallotus philippensis (Lam.) Muell.-Arg.,	Zingiber nimmonii Dalz.			Oplismenus burmannii (Retz.) P. Beauv.,	
Sapindus emarginatus Vahl	Rungia pectinata (L.) Nees				Terminalia bellirica (Gaertn.) Roxb.	
Wrightia tinctoria (Roxb.) R. Br.,	Sapindus emarginatus Vahl					
Ziziphus mauritiana Lam.,	Wrightia tinctoria (Roxb.) R. Br.,					

Table.15 Primary colonizers in landslide hit areas in Elival section

10° 52' 20.9892" N 76° 38' 13.884" E	10° 82' 34.707" N 76° 38' 4.466" E	10° 52' 36.336" N 76° 38' 22.2" E	10° 52' 41.088" N 76° 37' 59.16" E	10° 52' 43.348" N 76° 38' 0.659" E	10° 52' 45.077" N 76° 38' 1.346" E	10° 52' 27.444" N 76° 38' 26.196" E
Ailanthus excelsa Roxb.,	Caryota urens L.,	Ixora brachiata Roxb. ex DC.	Mallotus philippensis (Lam.) Muell.-Arg.,	Axonopus compressus (Sw.) P. Beauv.,	Panicum brevifolium L.,	Ageratum conyzoides L.,
Bombax cieba	Cipadessa baccifera (Roth) Miq.	Mallotus philippensis (Lam.) Muell.-Arg.,	Macaranga peltata (Roxb.) Muell.-Arg.	Panicum brevifolium L.,	Spilanthes radicans Jacq.,	Mitracarpus hirtus (L.) DC.
Cipadessa baccifera (Roth) Miq.	Ixora brachiata Roxb. ex DC.	Sapindus emarginatus Vahl	Mikania micrantha Kunth	Panicum notatum Retz.,	Synedrella nodiflora (L.) Gaertn.,	Rungia pectinata (L.) Nees
Combretum albidum G. Don,	Mallotus philippensis (Lam.) Muell.-Arg.,	Wrightia tinctoria (Roxb.) R. Br.,	Rungia pectinata (L.) Nees			
Eranthemum capense L.,	Sapindus emarginatus Vahl	Zingiber nimmonii Dalz.	Sapindus emarginatus Vahl			
Ficus hispida L. f.,	Wrightia tinctoria (Roxb.) R. Br.,		Wrightia tinctoria (Roxb.) R. Br.,			
Ziziphus mauritiana Lam.,						

III.3. Post flood effects and landslides in Nelliampathy Forest range

III.3.1. Nelliampathy range

The Nelliampathy Range comes under the Nemmara division along with two other ranges viz, Alathur and Kollengode. The range constitutes of 3 sections namely, Padagiri, Pothundi, Thiruvazhiyad. Major portion of the forest areas are situated as a contiguous block along the northern and western slope of Nelliampathy hills. Generally the terrain exhibits ruggedness, a range of altitudes and diversity with open rocky out crops and small patches of grasslands on highest points. Topographical features change abruptly as one proceeds from 40 m to higher elevation. The tract has a number of subsidiary ridges and valleys that extend in all directions connecting the main ridges. Nelliampathy range of hills have very high rocky pyramid like apexes and steep valleys. The highest peak is the Minnamaparamala with an elevation of 1,633 m above MSL. Other main peaks are (1) Palakappandimala with an elevation of 1,586 m, (2) Padagiri hill located in the middle on Nelliampathy RF, 1,520 m, (3) Pullalamala, 1,440 m and (4) Karappara with an elevation of 1,300 m above MSL. The lower hills are situated between 200 m and 900 m elevations above MSL.

Effects of flood in Nelliampathy Range

The media highlighted the heavy landslides in torrential rains in this range only during August 2018. As the hills are one of the favorite tourism spots of the district, the damages to the Ghat road to Nelliampathy disrupted the transport to this destination. The heavy landslides to the Ghat road from Pothundi to Kaikatty in Nelliampathy posed serious threats and damages to the species inhabiting the area. Visible habitat modification and species loss is evident in this area. In addition to this, several landslides within the range hit the people inhabiting Nelliampathy and the streams got flooded causing heavy damages to the riparian vegetation in the uphill area. Landslides and mudslides along with uprooting of trees were observed in between Pothundi to Kaikatti Ghat road, Chandramala, Palli, Kootengad, Vannathippalam, Brookland Estate, etc.

III.3.1.1. Pothundi to Kaikatti (Plates 23-26)

There were 13 locations between Pothundi and Kundaramchola were reported with landslides and mudslides. These were located from 10° 32' 6.4824" N and 76° 37' 16.698" E to 10° 31' 9.2496" N and 76° 37' 44.0328" E. Total of four landslides and nine mudslides

were identified in between this stretch. These places were having elevation between 23 Meter and 184 meter from sea level.

Mud slides

The minor mudslides occurred in width and depth of 1-4 meters. Nine locations were found to had mudslides (Plate 24: a-f).

Uprooted taxa

Uprooted taxa include *Mallotus philippensis*, *Grewia tilifolia*, *Bambusa bambos* and *Terminalia bellerica*. Due to the road construction to the hills, steep slopes had been formed and many of the tall trees got their roots exposed out. So the heavy rainfall and the soil erosion thereafter enhanced the uprooting of the tall trees during heavy rains.

Table.16. Location based data on effect of mudslide on vegetation from Pothundy to Kaikatti

Site	Location	Altitude	Uprooted Taxa
Location 1	10° 32' 6.4824" N 76° 37' 16.698" E	23m	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg., <i>Grewia tiliifolia</i> Vahl., <i>Bambusa bambos</i> (L.) Voss.
Location 2	10° 31' 54.4368" N 76° 37' 16.2948" E	118m	
Location 3	10° 31' 56.1" N 76° 37' 16.3416" E	110m	
Location 4	10° 31' 49.512" N 76° 37' 21.1152" E	105m	
Location 5	10° 31' 48.18" N 76° 37' 21.864" E	126m	
Location 7	10° 31' 37.524" N 76° 37' 30.6804" E	140m	<i>Terminalia bellirica</i> (Gaertn.) Roxb.
Location 10	76° 37' 37.9236" E 76° 37' 37.9236" E	149m	
Location 11	From 76° 37' 37.9236" E 76° 37' 37.9236" E	184m	
Location 12	From 76° 37' 37.9236" E 76° 37' 37.9236" E	184m	

Survivor Taxa

Large trees with deep root systems are the major survivors of the area. Some climbers like *Merremia umbellata*, *Tinospora cordifolia* and lianas like *Anamirta cocculus* also included in the survivor list. This indicates large trees and also the tree associated climbers also survived

the calamity. The survived taxa will suffer a higher temperature than the temperature before the calamity since the canopy cover had reduced due to uprooting of plants.

Table.17. Survivor taxa in mudslide hit area from Pothundi to Kaikatti

Location	Survivors
Location 1	<i>Helicteres isora</i> L., <i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Mallotus philippensis</i> (Lam.) Muell.-Arg., <i>Merremia umbellata</i> (L.) Hall., <i>Pennisetum polystachyon</i> (L.), <i>Tinospora cordifolia</i> (Willd.) Miers.
Location 2	<i>Anamirta cocculus</i> (L.) Wight & Arn., <i>Azadirachta indica</i> A.Juss., <i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Mallotus philippensis</i> (Lam.) Muell.-Arg., <i>Streblus asper</i> Lour.
Location 3	<i>Alstonia scholaris</i> (L.) R. Br., <i>Bombax ceiba</i> L., <i>Hibiscus surattensis</i> L., <i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Rhinacanthus nasutus</i> (L.) Kurz, <i>Tectona grandis</i> L., <i>Xylia xylocarpa</i> (Roxb.) Taub.
Location 4	<i>Ailanthus excelsa</i> Roxb., <i>Helicteres isora</i> L., <i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Mallotus philippensis</i> (Lam.) Muell.-Arg., <i>Trema orientalis</i> (L.) Blume
Location 5	<i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Tectona grandis</i> L., <i>Trema orientalis</i> (L.) Blume
Location 7	<i>Cipadessa baccifera</i> , <i>Grewia tiliifolia</i> Vahl, <i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Rhinacanthus nasutus</i> (L.) Kurz, <i>Trema orientalis</i> (L.) Blume
Location 10	<i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Peperomia pellucida</i> (L.) Kunth
Location 11	<i>Trema orientalis</i> (L.) Blume
Location 12	<i>Trema orientalis</i> (L.) Blume, <i>Macaranga peltata</i> (Roxb.) Muell.-Arg., <i>Helicteres isora</i> L.

Post Landslide modifications observed and Primary colonizers

Due to heavy rainfall, and the soil erosion occurred thereafter, the soil cover on the forest floor had reduced and now these areas have been inhabited by primary colonizers. These primary colonizers includes mainly of herbs and small shrubs which could easily complete their life cycle in thriving environments.

Table 18. Primary colonizers in mudslide hit areas from Pothundi to Kaikatti

Location	Primary colonizers
Location 1	<i>Achyranthus aspera</i> L., <i>Cayratia pedata</i> (Lam.) A. Juss. ex Gagnep., <i>Dicliptera foetida</i> (Forssk.) Blatt., <i>Dipteracanthus prostratus</i> (Poir.) Nees, <i>Sida cordifolia</i> L., <i>Sigesbeckia orientalis</i> L., <i>Croton hirtus</i> L'Herit.
Location 2	<i>Biophytum reinwardtii</i> (Zucc.) Klotzsch., <i>Blumea belangeriana</i> DC., <i>Chrysopogon aciculatus</i> (Retz.) Trin., <i>Dactyloctenium aegyptium</i> (L.) P. Beauv., <i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eragrostis tenella</i> (L.) P. Beauv. ex Roem. & Schult., <i>Eranthemum capense</i> L., L., <i>Glinus oppositifolius</i> (L.) A. DC., <i>Globba sessiliflora</i> Sim., <i>Mitracarpus hirus</i> (L.) DC., <i>Oplismenus burmannii</i> (Retz.) P. Beauv., <i>Pogostemon purpurascens</i> Dalz., <i>Spilanthes radicans</i> Jacq., <i>Tinospora cordifolia</i> (Willd.) Miers., <i>Solanum torvum</i> Sw., <i>Croton hirtus</i> L'Her.
Location 3	<i>Alternanthera sessilis</i> (L.) R. Br. ex. DC., <i>Biophytum reinwardtii</i> (Zucc.) Klotzsch., <i>Cleome burmannii</i> Wight & Arn., <i>Croton hirtus</i> L'Her., <i>Dicliptera foetida</i> (Forssk.) Blatt., <i>Merremia umbellata</i> (L.) Hall., <i>Pupalia lappacea</i> (L.) Juss., <i>Spilanthes radicans</i> Jacq.
Location 4	<i>Biophytum reinwardtii</i> (Zucc.) Klotzsch., <i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eragrostis tenella</i> (L.) P. Beauv. ex Roem. & Schult., <i>Eranthemum capense</i> L., <i>Momordica dioica</i> Roxb. ex Willd., <i>Naravelia zeylanica</i> (L.) DC., <i>Spilanthes radicans</i> Jacq., <i>Croton hirtus</i> L'Her., <i>Mimosa diplotricha</i> C. Wight ex Sanvalle
Location 5	<i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eragrostis tenella</i> (L.) P. Beauv. ex Roem. & Schult., <i>Eranthemum capense</i> L., <i>Momordica dioica</i> Roxb. ex Willd., <i>Pupalia lappacea</i> (L.) Juss., <i>Spilanthes radicans</i> Jacq.,
Location 7	<i>Blumea belangeriana</i> DC., <i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eranthemum capense</i> L., <i>Glinus oppositifolius</i> (L.) A. DC., <i>Oplismenus burmannii</i> (Retz.) P. Beauv., <i>Peperomia pellucida</i> (L.) Kunth, <i>Spilanthes radicans</i> Jacq.
Location 10	<i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eranthemum capense</i> L., <i>Helicteres isora</i> L., <i>Spilanthes radicans</i> Jacq.
Location 11	<i>Chrysopogon aciculatus</i> (Retz.) Trin., <i>Croton hirtus</i> L'Herit., <i>Laportea bulbifera</i> (Sieb. & Zucc.) Wedd., <i>Mimosa pudica</i> L., <i>Mitracarpus hirtus</i> (L.) DC., <i>Oplismenus burmannii</i> (Retz.) P. Beauv., <i>Rhynchoglossum notonianum</i> (Wall.) Burt.
Location 12	<i>Cayratia pedata</i> (Lam.) A. Juss. ex Gagnep., <i>Croton hirtus</i> L'Herit., <i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eranthemum capense</i> L., <i>Oplismenus burmannii</i> (Retz.) P. Beauv., <i>Spilanthes radicans</i> Jacq.,

Invading taxa in mudslide hit areas

During the heavy erosion, the propagules of invading taxa got widely dispersed and hence the taxa too. The major invaders include *Mikania micrantha*, *Chromolaena odorata*, *Mimosa pudica* and *synedrella nodiflora*. These invasive taxa may alter the natural vegetation of the forest area. The landslides gave a chance for the invasive taxa to spread over the area.

Table 19. Invasive taxa in mudslide hit areas in Nelliampathy hills (Pothundi-Kaikatti)

Location	Invaders
Location 1	Mikania micrantha Kunth., Triumfetta rhomboidea Jacq., Chromolaena odorata (L.) King & Robins., Synedrella nodiflora (L.) Gaertn.
Location 2	Mikania micrantha Kunth., Mimosa pudica L., Ageratum conyzoides L., Cleome viscosa L., Peperomia pellucida (L.) Kunth, Oxalis corniculata L., Synedrella nodiflora (L.) Gaertn., Sida acuta Burm. f.
Location 3	Mikania micrantha Kunth., Mimosa pudica L., Chromolaena odorata (L.) King & Robins., Peperomia pellucida (L.) Kunth, Synedrella nodiflora (L.) Gaertn., Triumfetta rhomboidea Jacq.
Location 4	Caesalpinia mimosoides Lam., Mimosa pudica L., Cleome viscosa L., Synedrella nodiflora (L.) Gaertn.
Location 5	Mimosa diplotricha C. Wight ex Sanvalle, Mimosa pudica L., Synedrella nodiflora (L.) Gaertn., Triumfetta rhomboidea Jacq.
Location 7	Mikania micrantha Kunth., Chromolaena odorata (L.) King & Robins., Oxalis corniculata L., Synedrella nodiflora (L.) Gaertn., Triumfetta rhomboidea Jacq.
Location 10	Synedrella nodiflora (L.) Gaertn., (L.) Gaertn., Chromolaena odorata (L.) King & Robins., Mikania micrantha Kunth., Ipomoea hederifolia L.
Location 11	Mikania micrantha Kunth, Triumfetta rhomboidea Jacq.
Location 12	Cleome viscosa L., Cyperus iria L., Mikania micrantha Kunth., Mimosa pudica L.

Landslides

Biggest landslides occurred in 800 m depth and 14m width at Kundarachola (Location 13). The three other landslides had a depth of 500 m and width of 20m (Plate 23: a-f) (Plate 26: a-f).

Uprooted taxa in the landslide hit areas

Bigger landslides harm the distribution of several taxa in the locality. Some of the uprooted taxa include Acronychia pedunculata, Allophylus concanicus, Alstonia venenata, Antidesma montanum, Xanthophyllum flavescens, Thunbergia fragrans, Smilax zeylanica, Rhinacanthus nastus, Piper umbellatum, Morinda tinctoria, Mallotus philippinensis, Jasminum coarctatum, Impatiens flaccida, Impatiens diversifolia, Helicteres isora, Globba ophioglossa, Epithema carnosum, Cipadessa baccifera, Henkelia fischeri etc. The loss of these taxa would seriously affect the area, since majority of them were large trees. Small herbs which grows under their canopy shade also get vanished from the area (Plate 25: a-f).

Table 20. Location based data on effect of landslide on vegetation (Pothundi-Kaikatti)

Site	Location	Altitude	Uprooted Taxa
Location 6	10° 31' 47.1" N 76° 37' 22.9224" E	110m	Acronychia pedunculata (L.) Miq., Thunbergia fragrans Roxb., Smilax zeylanica L., Helicteres isora L., Morinda pubescens Sm., Jasminum coarctatum Roxb.
Location 8	10° 31' 31.98" N 76° 37' 33.96" E	144m	Impatiens flaccida Arn., Impatiens diversifolia B.Heyne ex Wight & Arn., Globba sessiliflora Sims, Alstonia venenata R.Br., Jasminum coarctatum Roxb.
Location 9	10° 31' 31.4616" N 76° 37' 37.9236" E	179m	Epithema dentatum subsp. hispidum (C.B.Clarke) Hilliard & B.L.Burt, Henckelia fischeri (Gamble) A.Weber & B.L.Burt, Piper umbellatum L.
Location 13	10° 31' 9.2496" N 76° 37' 44.0328" E	160m	Allophylus concanicus Radlk. var. lanceolatus Gamble, Antidesma montanum Blume, Xanthophyllum flavescens Roxb., Mallotus philippensis (Lam.) Müll.Arg. Cipadessa baccifera (Roth) Miq., Helicteres isora L.

Table 21. Survivor taxa in landslide hit area from Pothundi to Kaikatti

Location	Survivors
Location 6	Grewia tiliifolia Vahl, Helicteres isora L., Macaranga peltata (Roxb.) Muell.- Arg., Tectona grandis L., Trema orientalis (L.) Blume
Location 8	Erythrina stricta Roxb., Grewia tiliifolia Vahl, Terminalia bellirica (Gaertn.) Roxb.,
Location 9	Grewia tiliifolia Vahl, Helicteres isora L., Macaranga peltata (Roxb.) Muell.- Arg.
Location 13	Ailanthus excelsa Roxb., Arenga wightii Griff., Chionanthus mala-elengi (Dennst.) P. S. Green, Jasminum malabaricum Wight, Trema orientalis (L.) Blume

Table 22. Primary colonizers in landslide hit areas in Nelliampathy hills (Pothundi to Kaikatti)

Location	Primary Colonizers
Location 6	<i>Abutilon indicum</i> (L.) Sweet, <i>Apluda mutica</i> L., <i>Biophytum reinwardtii</i> (Zucc.) Klotzsch., <i>Blumea belangeriana</i> DC., <i>Spilanthes radicans</i> Jacq., <i>Tragia involucrata</i> L., <i>Vernonia cinerea</i> (L.) Less.
Location 8	<i>Mitracarpus hirtus</i> (L.) DC., <i>Phyllanthus amarus</i> Schum. & Thonn., <i>Xenostegia tridentata</i> (L.) Austin & Staples, <i>Spilanthes radicans</i> Jacq., <i>Croton hirtus</i> L'Her.
Location 9	<i>Blumea belangeriana</i> DC., <i>Croton hirtus</i> L'Her., <i>Digitaria ciliaris</i> (Retz.) Koeler, <i>Eranthemum capense</i> L., <i>Ipomoea hederifolia</i> L., <i>Peperomia pellucida</i> (L.) Kunth, <i>Pouzolzia zeylanica</i> (L.), <i>Spilanthes radicans</i> Jacq.,
Location 13	<i>Mitracarpus hirtus</i> (L.) DC., <i>Oplismenus burmannii</i> (Retz.) P. Beauv., <i>Chrysopogon aciculatus</i> (Retz.) Trin., <i>Rhinacanthus nasutus</i> (L.) Kurz, <i>Rhynchoglossum notonianum</i> (Wall.) Burt, <i>Elatostema acuminatum</i> (Poir.) Brongn., <i>Laportea bulbifera</i> (Sieb. & Zucc.) Wedd.,

Table 23. Invasive taxa in landslide hit areas in Nelliampathy hills (Pothundi to Kaikatti)

Location	Invaders
Location 6	<i>Mikania micrantha</i> Kunth., <i>Cleome viscosa</i> L., <i>Mimosa pudica</i> L., <i>Passiflora foetida</i> L., <i>Cyperus iria</i> L., <i>Triumfetta rhomboidea</i> Jacq.
Location 8	<i>Mikania micrantha</i> Kunth., <i>Mimosa diplotricha</i> C. Wight ex Sanvalle, <i>Synedrella nodiflora</i> (L.) Gaertn., (L.) Gaertn., <i>Chromolaena odorata</i> (L.) King & Robins.
Location 9	<i>Synedrella nodiflora</i> (L.) Gaertn., <i>Senna occidentalis</i> (L.), <i>Triumfetta rhomboidea</i> Jacq.
Location 13	<i>Mikania micrantha</i> Kunth, <i>Mimosa pudica</i> L., <i>Triumfetta rhomboidea</i> Jacq., <i>Croton hirtus</i> L'Herit.

III.3.1.2. Chandramala, Nooradi- Brookeland

Tea and coffee plantations owned by government and private landlords are the backbone of the high range economy and life. The upsetting events occurred during the time of flood disrupted the essential needs of transport and water were cut down in these estates. The estates were reported with severe loss of land and the vegetation. The area spanning from latitude of 10° 26' 52.0548" N and 76° 39' 40.8024" E to 10° 31' 49.7388" N and 76° 42' 8.7048" E witnessed landslides and mudslides which cost the plantation thousands of rupees by the loss of the crops. There are 12 such locations in the mentioned area from Chandramalagiri to Brooke land. These locations are situated in an elevation ranging from 870 meters to 1004 meters above the sea level.

Apart from the massive landslide in the hamlet of Brooke land, all the landslides were relatively medium sized having depth and length between 10-15 meters. Brooke land the habitat of migrant workers was highly affected where the land slide occurred in about 1000-meter depth and 150-meter width. *Coffea arabica* L., *Macaranga peltata* (Roxb.) Muell.-Arg, *Lepisanthes tetraphylla* (Vahl) Radlk., *Syzygium densiflorum* Wall. ex Wight & Arn., *Ficus racemosa* L., *Syzygium densiflorum* Wall. ex Wight & Arn., *Grevillea robusta* Cunn. and *Cullenia exarillata* Robyns, were the major trees uprooted in this area. The loss of *Coffea*, *Camellia* and *Cullenia* was highly impacted by various means. The economy reported with huge loss due to the destruction of coffee and tea plants (**Plates 27-29**). *Cullenia*, the tree essential for the survival of lion tailed macaque has been lost in significant numbers. This led the animal to extend its search for food in the inhabiting areas and roads. This is a serious threat for the life of this endangered species.

Primary colonizers in these areas were more diverse but lesser in number. Invader species flourished and almost completely occupied the affected sites. Primary colonizers reported are *Crassocephalum crepidioides* (Benth.) S. Moore, *Parthenium hysterophorus* L., *Crotalaria spectabilis* Roth, *Ageratina adenophora* (Spreng.) King & Robins., *Bidens pilosa* L. var. *minor* (Blume) Sherff, *Richardia scabra* L., *Mimosa pudica* L., *Acmella paniculata* (Wall. ex DC.) R.K. Jansen, etc.

The invaders occupied the major area include *Mecardonia procumbens* (Mill.) Small, *Mikania micrantha* Kunth, *Ageratum conyzoides* L., *Ageratum houstonianum* Mill., *Mitracarpus hirtus* (L.) DC., etc. The rejuvenation process of vegetation is in slow pace due to the lack of sufficient water supply to the plants.

**Table.24. Location based data on Landslide and mudslides at Nelliampathy
(Chandramala to Brookeland)**

Site	Latitude	Longitude	Altitude
Chandramala giri shed	10° 31' 49.7388" N	76° 42' 8.7048" E	900 m
	10° 31' 37.0164" N	76° 42' 14.346" E	875 m
Kottengad { Check dam }	10° 31' 27.3216" N	76° 42' 21.366" E	870 m
Kottengad { Car bend }	10° 31' 2.8416" N	76° 42' 20.7252" E	870 m
Kottengad [Way to Dam]	10° 31' 7.6584" N	76° 42' 19.746" E	876 m
Kottengad [Way to Dam]	10° 31' 9.7644" N	76° 45' 52.0308" E	888 m
Vannathipalam	10° 28' 49.836" N	76° 40' 13.9512" E	894 m
Palli	10° 27' 26.9496" N	76° 40' 16.1616" E	912 m
	10° 27' 24.0264" N	76° 40' 14.0088" E	982 m
	10° 27' 22.6404" N	76° 40' 12.2484" E	1004 m
Brooke Land	10° 27' 2.8908" N	76° 39' 50.2236" E	970 m
	10° 26' 52.0548" N	76° 39' 40.8024" E	962 m

Table 25. Primary colonizers and invaders in different landslide areas in Nelliampathy hills

Chandramala giri shed - Location 1		Chandramala Location 2	
Primary colonizers	Invaders	Primary colonizers	Invaders
Acmella paniculata (Wall. ex DC.) R.K. Jansen,	Ageratum conyzoides L.,	Crassocephalum crepidioides (Benth.) S. Moore,	Ageratum conyzoides L.,
Bryophyllum pinnatum (Lam.) Kurz,	Ageratum houstonianum Mill.,	Achyranthes aspera L.,	Ageratum houstonianum Mill.,
Camellia sinensis (L.) O.Ktze.,	Mecardonia procumbens (Mill.) Small,	Boerhavia diffusa L.,	Chromolaena odorata (L.) King & Robins.
Euphorbia hirta L.,	Mikania micrantha Kunth	Cardiospermum halicacabum L.,	Hevea braziliensis (Willd. ex A. Juss.) Muell.-Arg.,
Haplanthodes neilgherryensis (Wight) Majumdar,	Oxalis corniculata L.,	Cyanotis pilosa Schult. & Schult.	Mecardonia procumbens (Mill.) Small,
Mimosa pudica L.,	Solanum americanum Mill.,	Cyperus iria L.,	Mitracarpus hirtus (L.) DC.,
Mitracarpus hirtus (L.) DC.,		Drymaria cordata (L.) Willd. ex Roem. & Schult. ssp. diandra (Blume) Duke	Parthenium hysterophorus L.,
Parthenium hysterophorus L.,		Scoparia dulcis L.,	Solanum americanum Mill.,
Sida rhombifolia L.,		Sida rhombifolia L.,	
Tridax procumbens L.,		Torenia hirsuta Willd.,	

Primary colonizers and invaders in different landslide areas in Nelliampathy hills (contd.)

Kottengad {Check dam}		Kottengad {Car bend}		
Primary colonizers	Invaders	Primary colonizers	Invaders	Uprooted
Mimosa pudica L.,	Ageratum conyzoides L.,	Mitracarpus hirtus (L.) DC.,	Ageratum conyzoides L.,	Ficus racemosa L.,
Mitracarpus hirtus (L.) DC.,	Ageratum houstonianum Mill.,	Acmella paniculata (Wall. ex DC.) R.K. Jansen,	Ageratum houstonianum Mill.,	Syzygium densiflorum Wall. ex Wight & Arn.,
Parthenium hysterophorus L.,	Mecardonia procumbens (Mill.) Small,	Centella asiatica (L.) Urban	Mecardonia procumbens (Mill.) Small,	Grevillea robusta Cunn.
Spilanthes radicans Jacq.,	Mikania micrantha Kunth	Crassocephalum crepidioides (Benth.) S. Moore,	Mikania micrantha Kunth	
Tridax procumbens L.,	Oxalis corniculata L.,	Eragrostis tenella (L.) P. Beauv.	Oxalis corniculata L.,	
		Lantana camara L.,		
		Mimosa pudica L.,		
		Pennisetum pedicellatum Trin.,		
5.Kottengad { Way to Dam}		6.Kottengad { Way to Dam}		
Primary colonizers	Invaders	Primary colonizers	Invaders	Uprooted
Crassocephalum crepidioides (Benth.) S. Moore,	Mecardonia procumbens (Mill.) Small,	Richardia scabra L.,	Mecardonia procumbens (Mill.) Small,	Spondias pinnata (L. f.) Kurz,
Camellia sinensis (L.) O.Ktze.,	Mikania micrantha Kunth	Crassocephalum crepidioides (Benth.) S. Moore,	Mikania micrantha Kunth	Grevillea robusta Cunn.
Parthenium hysterophorus L.,	Oxalis corniculata L.,	Camellia sinensis (L.) O.Ktze.,	Oxalis corniculata L.,	
Mimosa pudica L.,		Parthenium hysterophorus L.,		
Crotalaria spectabilis Roth,		Mimosa pudica L.,		
Vernonia cinerea (L.) Less.,		Bidens pilosa L. var. minor (Blume) Sherff,		
Ageratina adenophora (Spreng.) King & Robins.,				
Bidens pilosa L. var. minor (Blume) Sherff,				

Primary colonizers and invaders in different landslide areas in Nelliampathy hills (contd.)

Vannathi palam			Palli		
Primary colonizers	Invaders	Uprooted	Primary colonizers	Invaders	Uprooted
Parthenium hysterophorus L.,	Ageratum conyzoides L.,	Macaranga peltata (Roxb.) Muell.-Arg	Scoparia dulcis L.,	Ageratum houstonianum Mill.,	Coffea arabica L.,
Mimosa pudica L.,	Ageratum houstonianum Mill.,	Coffea arabica L.,	Richardia scabra L.,	Mecardonia procumbens (Mill.) Small,	Cullenia exarillata Robyns,
Richardia scabra L.,	Mecardonia procumbens (Mill.) Small,		Mitracarpus hirtus (L.) DC.,	Mikania micrantha Kunth	
Acmella paniculata (Wall. ex DC.) R.K. Jansen,	Mikania micrantha Kunth		Ageratina adenophora (Spreng.) King & Robins.,	Chromolaena odorata (L.) King & Robins.	
Euphorbia hirta L.,			Bidens pilosa L. var. minor (Blume) Sherff,		
Mitracarpus hirtus (L.) DC.,			Helichrysum wightii Clarke ex Hook.		
Parthenium hysterophorus L.,					
Sida rhombifolia L.,					
Tridax procumbens L.,					
Ageratina adenophora (Spreng.) King & Robins.,					

Primary colonizers and invaders in different landslide areas in Nelliampathy hills (contd.)

Location 9				Location 10			
Primary colonizers	Invaders	Uprooted	Survivors	Primary colonizers	Invaders	Uprooted	Survivors
Ageratina adenophora (Spreng.) King & Robins.,	Oxalis corniculata L.,	Syzygium cumini (L.) Skeels,	Chukrasia tabularis A. Juss.,	Ageratina adenophora (Spreng.) King & Robins.,	Oxalis corniculata L.,	Syzygium cumini (L.) Skeels,	Ficus microcarpa L.
Bidens pilosa L. var. minor (Blume) Sherff,		Premna tomentosa Willd.,	Ficus microcarpa L.	Bidens pilosa L. var. minor (Blume) Sherff,	Ageratum conyzoides L.,	Coffea arabica L.,	Cullenia exarillata Robyns
Syzygium cumini (L.) Skeels,		Coffea arabica L.,		Syzygium cumini (L.) Skeels,	Ageratum houstonianum Mill.,	Ficus microcarpa L.	
Premna tomentosa Willd.,		Ficus microcarpa L.		Chukrasia tabularis A. Juss.,	Chromolaena odorata (L.) King & Robins.	Cullenia exarillata Robyns	
Chukrasia tabularis A. Juss.,							

Primary colonizers and invaders in different landslide areas in Nelliampathy hills (Contd.)

Brooke Land		
Primary colonizers	Invaders	Uprooted
Eryngium foetidum L.,	Ageratum conyzoides L.,	Coffea arabica L.,
Achyranthes aspera L.,	Ageratum houstonianum Mill.,	Cullenia exarillata Robyns,
Ageratina adenophora (Spreng.) King & Robins.,	Mecardonia procumbens (Mill.) Small,	Litsea coriacea (Heyne ex Meisner) Hook.
Amaranthus spinosus L.,	Mikania micrantha Kunth	Macaranga peltata (Roxb.) Muell.-Arg
Bidens pilosa L. var. minor (Blume) Sherff,	Mitracarpus hirtus (L.) DC.,	Schleichera oleosa (Lour.) Oken,
Blumea belangeriana DC.,	Oxalis corniculata L.,	
Coffea arabica L.,	Parthenium hysterophorus L.,	
Crassocephalum crepidioides (Benth.) S. Moore,	Solanum americanum Mill.,	
Croton hirtus L'Herit.,	Solanum torvum Sw.,	
Cyanotis papilionacea (Burm. f.) Schult.	Synedrella nodiflora (L.) Gaertn.,	
Cyperus diffusus Vahl,		
Kyllinga bulbosa P. Beauv.,		
Macaranga peltata (Roxb.) Muell.-Arg		
Persicaria chinensis (L.) Gross.		
Spermacoce latifolia Aubl.		
Spilanthes radicans Jacq.,		
Cyrtococcum oxyphyllum (Steud.) Stapf in Hook.		
Oplismenus burmannii (Retz.) P. Beauv.,		

Location 12			
Primary colonizers	Invaders	Uprooted	Survivors
Ageratina adenophora (Spreng.) King & Robins.,	Ageratum houstonianum Mill.,	Cullenia exarillata Robyns,	Cullenia exarillata Robyns,
Crassocephalum crepidioides (Benth.) S. Moore,	Mecardonia procumbens (Mill.) Small,	Syzygium cumini (L.) Skeels,	Syzygium cumini (L.) Skeels,
Cyrtococcum oxyphyllum (Steud.) Stapf in Hook.	Mikania micrantha Kunth		
Oplismenus burmannii (Retz.) P. Beauv.,	Oxalis corniculata L.,		
	Solanum americanum Mill.,		

III.4. Post flood effects and landslides in Kollengode Forest range

III.4.1. Kollengode range

Kollengode forest range under Nemmara forest division forms the northern end of Anamalai sub unit of Western Ghats. The area fall within the latitudinal range of 10° 25' 0" N - 10° 55' 0" N and longitudinal dimensions of 76° 35' 0" E - 76° 55' 0" E. The region is endowed with 68 sq.km. vested forests towards the south of Palghat Gap. The region is endowed with varied altitudinal gradients and ranges between 100m -1634 m from msl. The hill tracts of the Ghats of Kollengode range can be delineated into two parts, Puramalavaram and Akamalavaram based on their location with respect to the Palghat gap. The forest types met within Akamalavaram can be divided into Southern Tropical Wet evergreen Forests, Southern Tropical semi-evergreen Forests and grasslands as these tracts were lying in less proximity with Palghat gap. The important hill tracts of Akamalavaram include Anamada, Karashoori, Mattumala Manpara, Mattumala, Minnampara Pothumala and Vazhakundu. South Indian moist deciduous forests that form major forest type in the Puramalavaram tracts, as these hill tracts are more proximity to the Gap features. The important hill tracts of Puramalavaram comprises Chathampara hills, Kilimala, Palakappandi, Seetharkundu and Vazhukkapara. In addition to the hill tracts of main ghats, the range is also endowed with nearly 25 isolated low altitude hillocks occurring as bits in the gap region.

In the main Ghat area landslides occurred in Vazhakundu on the eastern sides of Pothumala where narrow endemic species have already been recorded. Moreover, localities in Anamada and Mattumala also experienced mud slides and these are sites of many endemic taxa.

III.4.1.1. Vazhakkund (Plate 30. Fig.a-f)

Vazhakkund is located in the Kollengode range was seriously devastated by the flood during monsoon season. This location lies at latitude of 10° 54' 58.0248" N and longitude 76° 42' 53.3448" E with an elevation of 865 meter from the sea level. The landslide hit at 50 meter width and the soil from at least 1000 meter depth got removed. *Litsea laevigata* (Nees) Gamble was the major tree species uprooted at the site. Even though the soil eroded in a drastic manner trees like *Santalum album*, *Ficus exasperata* and shrubs and Herbs like *Colebrookia oppositifolia*, *Sigesbeckia orientalis* and *Crassocephalum crepioides* were survived. Along with the trees, dependant climbers *Clematis gouriana* and *Piper longum*

survived the landslide. After the loss of soil and plants the canopy is opened which exposed the land directly to sunlight. This opening in the semi- evergreen forest led to the invasion of several invasive species like *Ageratum conyzoides*, *Crassocephalum crapidioides*, *Cyperus iria*, *Kyllinga bulbosa*, *Laportea camara*, *Mikania micrantha*, *Mimosa pudica* and *Spilanthes radicans*. Primary colonizers like *Callicarpa tomentosa*, *Derris scandens*, *Ipomoea hederifolia*, *Kluggia notoniana*, *Phaulopsis imbricata*, *Rungia repens* and *Trema orientalis* are establishing in good pace in this region after the flood.

The herbaceous elements in survivor taxa include *Sigesbeckia orientalis* L. (Indian weed) *Crassocephalum crepidioides* (Benth.) S. Moore. (Fire weed) usually inhabit forest shades near plantations as well as clearings. *Sigesbeckia orientalis* L. possess strong tap root with spreading branches and considered to have weed potential and is invasive in nature in several pacific islands. *Crassocephalum crepidioides* (Benth.) S. Moore. (Fire weed) with moderate invasive and weed potentials have no seed dormancy and retain viability after room storage for 10 months. These adaptive traits might be the reason for their survival in landslide areas. The climbers *Piper longum* L. and *Clematis gouriana* Roxb. ex DC were also survived from landslide. Presence of extensive root system with root suckers in *Santalum album* L. and Strangling habit as well as aerial roots in *Ficus exasperata* Vahl. may be contributed for successful survival of these taxa in this region after flood and landslide.

Post Landslide modifications observed and Primary colonizers

Among the primary colonizers, *Callicarpa tomentosa* (L.) L., *Jatropha gossypifolia* L., *Macaranga peltata* (Roxb.) Muell.-Arg. and *Trema orientalis* (L.) Blume are considered to be the prominent species found in secondary forest formation. These species usually inhabits and prefer disturbed open areas in evergreen as well as in semi-evergreen patches than in forest interiors. Likewise the herbaceous taxa such as *Rungia repens* (L.) Nees, *Phaulopsis imbricata* (Forssk.) Sweet. and *Rhynchoglossum notonianum* (Wall.) Burt which were usually seen in open chasmophytic habitats were found to occur in the open up and cleared landslide modified habitats in semievergreen patches. The species such as *Solanum americanum* Mill., *Solanum aculeatissimum* Jacq. and *Ipomoea hederifolia* L. were representatives of degraded forest elements. This indicates the degraded nature of vegetation in landslide effected regions.

Invading taxa in landslide hit area in Vazhakkundu

The taxa such as *Lantana camara* L., *Mikania micrantha* Kunth. and *Ageratum conyzoides* L. were commonly occurring invasive taxa found in disturbed open areas of forest tracts of Kollengode. Emergence of this species in the semi evergreen patches in landslide areas reveals their invasiveness. It is also noted that the development of taxa such as *Tragia involucrata* L. which grow aggressively as a dry land weed shows the modified status of the vegetation after landslide. Similarly the presence of weed taxa such as *Cyperus iria* L., *Cyperus zollingeri* Steud., *Spilanthes radicans* Jacq., *Mimosa pudica* L., *Kyllinga bulbosa* P. Beauv. etc which usually found in shady moist deciduous patches also indicate the cascading effect of changed environmental conditions as a result of land collapse.

III.4.1.2. Mattumala

Mattumala form one of the most diverse hill tracts of Akamalavaram region of Kollengode forests which fall within the geographical coordinates 10°31'43.0"N latitude and 76°43'10.0"E longitude. The elevation of the area ranges from 1000m -1300m from msl. Evergreen vegetation with grassland patches at the top forms the peculiar feature of the region. The grassland patches was floristically diverse with its own rich floral associations. The common grass species found in this region include *Arundinella ciliata* (Roxb.) Nees ex Miq., *Chrysopogon nodulibarbis* (Hochst. ex Steud.) Henrard, *Cymbopogon flexuosus* (Nees ex Steud.) W.Watson, *Isachne setosa* C.E.C.Fisch. and *Jansenella griffithiana* (C. Muell.) Bor. etc. Grassland also inhabits a good population of *Phoenix loureiroi* Kunth.

Amidst the grassy patches, numerous small herbaceous taxa thrives with its own microhabitats. Important species include *Burmannia coelestis* D.Don, *Hypoxis aurea* Lour., *Curculigo orchioides* Gaertn, *Alysicarpus bupleurifolius* (L.) DC., *Crotalaria calycina* Schrank, *Crotalaria multiflora* (Arn.) Benth., *Smithia conferta* Sm., *Smithia gracilis* Benth., *Phyllanthus rheedei* Wight, *Justicia neesii* Ramamoorthy, *Utricularia striatula* Smith, *Aeginetia pedunculata* Wall. *Striga asiatica* (L.) Kuntze, *Neanotis indica* (DC.) W.H.Lewis, *Neanotis rheedei* (Wight & Arn.) W. H. Lewis, *Neanotis tubulosa* (G. Don) Mabb. *Impatiens sasadharanii* var. *sasadharanii* K. M. P. Kumar, Omalsree, Hareesh & V. B. Sreek., *Impatiens sasadharanii* var. *hirsuta* K. M. P. Kumar, Omalsree, Hareesh & V. B. Sreek. etc.

The region hosts rich diversity of orchids most of which exhibits endemism. *Brachycorythis iantha* (Wight) Summerh., *Brachycorythis splendida* Summerh., *Crepidium purpureum* (Lindl.) Szlach., *Habenaria barnesii* Summerh. Ex C. E. C. Fisch., *Habenaria*

crinifera Lindl. *Habenaria rariflora* A.Rich. and *Pachystoma hirsutum* (Joseph & Vajr.) Sathish & Manilal forms the important Orchidaceae members inhabiting the region.

Other prominent taxa prevailing in this region comprise *Scutellaria wightiana* Benth, *Arisaema tortuosum* (Wall.) Schott, *Asparagus gonoclados* Baker, *Rubus niveus* Thunb, Mini & Sivadasan, *Impatiens scapiflora* B.Heyne ex Roxb, *Sonerila wallichii* Benn., *Swertia angustifolia* Buch.-Ham. ex D. Don, *Torenia travancorica* Gamble, *Anaphalis lawii* (Hook.f.) Gamble, *Anaphalis subdecurrens* (DC.) Gamble, *Emilia scabra* DC., *Launaea acaulis* (Roxb.) Babc. ex Kerr, *Phyllocephalum courtallense* (Wight) Narayana, *Peucedanum anamallayense* C. B. Clarke, *Pimpinella heyneana* (DC.) Benth. etc

The heavy mudslide in the slopes of this grassland washed off the rheophytic habitat and the associated chasmophytic taxa (Plates 31-32).

III.4.1.3. Anamada

Anamada region comprises evergreen and semi-evergreen forest patches amidst the coffee plantations and form part of Kollengode forests. The area lies within 10°31'51.0"N latitudes and 76°44'45.0"E longitudes. The region is highly diverse with endemic tree species, climbers and herbs.

Mud slide experienced in regions adjacent to coffee plantations has affected habitat of numerous herbaceous taxa such as *Biophytum intermedium* Wight, *Sonerila wallichii* Benn., *Arisaema leschenaultii* Blume, *Andrographis atropurpurea* (Dennst.) Alston, *Asystasia crispata* Benth., *Alpinia malaccensis* (Burm.f.) Roscoe, *Pilea melastomoides* (Poir.) Wedd. *Begonia floccifera* Bedd., *Argostemma courtallense* Arn., *Dichrocephala integrifolia* (L.f.) Kuntze., *Scutellaria violacea* B. Heyne ex Benth., *Crepidium purpureum* (Lindl.) Szlach. *Rhopalephora scaberrima* (Blume) Faden etc. (Plate 33).

III.5. Post flood effects and landslides in Low altitude hillocks

The Palghat Gap region of southern Western Ghats are characterized by low altitude rocky outcrops which are habitats for many taxa. The heavy downpour in August 2018 caused serious threats to the micro habitats existing in these sites by way of washing up off soil filled areas on these exposed granitic systems. The study monitored the changes in microhabitats of these granitic systems and how species survival in these areas got affected. The study addressed a post flood analysis of damage and change in vegetation pattern in the following hillocks.

III.5. 1. Ottappalam Forest Range

Anangan Mala (Plates 34-36)

Anangan Mala a medium sized hill extended up to 18 kilo meters from Kizhur to Ambalappara was largely affected by the flood hit the state in August 2018. Three different massive landslides occurred in the Ananganmala region.

Malachippara (Plate 34: a-f)

This area lies in the latitude of 10° 49' 15.783"N and longitude of 76° 23' 51.887"E at an elevation of 395 ft from sea level. Soil run off in a depth of 500 M from the top of the hill with a 50 meter width was observed in the site. Large number of trees were seen uprooted and the survival rate was poor. *Terminalia bellerica*, *Phyllanthus emblica*, *Pterocarpus marsupium*, *Anacardium occidentale*, *Sweitenia macrophylla*, *Bambusa bambos* and *Pongamia pinnata* are the major plant species recorded as uprooted ones. The rubber plantation in the location has experienced significant loss in number of trees. Soil and rocks were accumulated at the base of the hill at private properties in the nearby locations. The vegetation survived primarily consists of small herbs, shrubs and few tree species. The survivor list include *Ailanthus excelsa* Roxb., *Aphuda mutica* L., *Azadirachta indica* A. Juss., *Calycopteris floribunda* Lam., *Mimosa pudica* L., *Glycosmis pentaphylla* (Retz.) DC., *Tectona grandis* L. f.etc. The geographical features influenced survival of these species and these survivors were away from the locations from where the soil erosion occurred.

Primary colonizers and survivors

Primary colonizers growing in quick pace in the region includes *Cassia fistula* L., *Grewia tiliifolia* Vahl, *Hyptis suaveolens* (L.) Poit., *Oldenlandia corymbosa* L., and *Vernonia cinerea* (L.) Less.,. *Cheilanthes*, *Pityrogramma* and *Lygodium* are the pteridophyte species are still existing in the range. *Mikania micrantha* is the common invasive species extended widely in the region. The data is summarized in the following table.

Table 26. Primary colonizers and survivors

Primary Colonizers	Survivors
Cassia fistula L.,	Ailanthus excelsa Roxb.,
Dipteracanthus prostratus (Poir.) Nees in Wall.,	Apluda mutica L.,
Evolvulus alsinoides (L.) L.,	Azadirachta indica A.Juss.
Grewia tiliifolia Vahl,	Calycopteris floribunda Lam.,
Hyptis suaveolens (L.) Poit.,	Canthium coromandelicum (Burm. f.) Alston
Microstachys chamaelea (L.) Muell.-Arg.,	Chromalaena odorata (L.) King & Robins.,
Mitracarpus hirus (L.) DC.,	Cleistanthus collinus (Roxb.) Benth. ex Hook.f.,
Oldenlandia corymbosa L.,	Ficus hispida L. f.,
Pennisetum polystachyon (L.)	Glycosmis pentaphylla (Retz.) DC.,
Senna occidentalis (L.) Link,	Macaranga peltata (Roxb.) Muell.-Arg.
Stachytarpheta jamaicensis (L.) Vahl,	Mimosa pudica L.,
Trema orientalis (L.) Blume	Morinda pubescens J. E. Smith
Vernonia cinerea (L.) Less.,	Naregamia alata Wight & Arn.,
	Santalum album L.,
	Tectona grandis L. f.
	Ziziphus oenoplia (L.) Mill.,

Athirappara (Plate 35: a-f)

The second site where the land slide occurred is located half a kilometre from the human settlement. The affected area is located in 10° 49' 31.529"N and 76° 23' 0.551"E at an elevation of 489 ft. The landslide occurred in 20 meter width by removing soil up to 300 meter. The origin of the landslide was at the top of the hill and the effect extended up to the bottom of the hill where the households were situated. Even though the location was inside the forest, the effects were comparatively lesser compared to the first location. The major species were uprooted are *Terminalia bellerica*, *Phyllanthus emblica*, *Pterocarpus marsupium*, *Sweitenia macrophyll* and *Pongamia pinnata*. Since the sand erosion and deposition occurred in the rocky area without much vegetation cover, the loss of vegetation is comparatively low. The survivor species include *Ailanthus excels Roxb.*, *Calycopteris floribunda Lam.*, *Ficus hispida L. f.*, *Holerrhena pubescens (Buch.-Ham.) Wall. ex G. Don*, *Macaranga peltata (Roxb.) Muell.- Arg.* *Terminalia paniculata Roth.* etc.. Uprooted species were grown on the rocky area. The plants which escaped the slide were away from the rocky surface and were distributed in areas where there was sufficient soil.

Primary colonizers and survivors

The site is under resurrection in the case of vegetation by the growth of primary colonizers like *Blumea belangeriana* DC., *Dipteracanthus prostratus* (Poir.) Nees in Wall., *Ficus racemosa* L., *Microstachys chamaelea* (L.) Muell.-Arg., *Oldenlandia corymbosa* L., *Stachytarpheta jamaicensis* (L.) Vahl, and pteridophytes like *Cheilanthes*, *Pityrogramma* and *Lygodium* etc. *Lantana camara* L., and *Mikania micrantha* Kunth. are the invasive species occupying the area and are colonizing the landslide hit area.

Table 27. Primary colonizers and survivors in Athirappara

Survivors	Primary colonizers
<i>Ailanthus excelsa</i> Roxb.,	<i>Blumea belangeriana</i> DC.
<i>Azadirachta indica</i> A.Juss.	<i>Canscora diffusa</i> (Vahl) R. Br. ex Roem. & Schult.,
<i>Calycopteris floribunda</i> Lam.,	<i>Cassia fistula</i> L.,
<i>Canthium coromandelicum</i> (Burm. f.) Alston	<i>Chromalaena odorata</i> (L.) King & Robins.,
<i>Chromalaena odorata</i> (L.) King & Robins.,	<i>Dipteracanthus prostratus</i> (Poir.) Nees in Wall.,
<i>Cyclea peltata</i> (Lam.) Hook. f. & Thoms.	<i>Ficus racemosa</i> L.,
<i>Ficus hispida</i> L. f.,	<i>Hyptis suaveolens</i> (L.) Poit.,
<i>Glycosmis pentaphylla</i> (Retz.) DC.,	<i>Ipomoea triloba</i> L.,
<i>Holerrhena pubescens</i> (Buch.-Ham.) Wall. ex G. Don,	<i>Leucas aspera</i> (Willd.) Link
<i>Macaranga peltata</i> (Roxb.) Muell.-Arg.	<i>Microstachys chamaelea</i> (L.) Muell.-Arg.,
<i>Morinda pubescens</i> J. E. Smith	<i>Mimosa pudica</i> L.,
<i>Naregamia alata</i> Wight & Arn.,	<i>Mitracarpus hirus</i> (L.) DC.,
<i>Racosperma auriculiforme</i> (Benth.) Pedley,	<i>Oldenlandia corymbosa</i> L.,
<i>Santalum album</i> L.,	<i>Pennisetum polystachyon</i> (L.)
<i>Terminalia paniculata</i> Roth,	<i>Phyllanthus amarus</i> Schum. & Thonn
<i>Xylia xylocarpa</i> (Roxb.) Taub.,	<i>Simarouba glauca</i> DC.,
	<i>Stachytarpheta jamaicensis</i> (L.) Vahl,
	<i>Trema orientalis</i> (L.) Blume
	<i>Vernonia cinerea</i> (L.) Less.,

Vettukad (Plate 36: a-f)

Vettukad was the area which witnessed the landslide in the highest magnitude across the Ananganmala Hills. The area is situated in 10° 50' 6.229" N and 76° 21' 24.551"E. It has an elevation of 446 ft from the sea level. Large number of trees and other small plants were either uprooted or washed off. The vegetation was cleared in a stretch of 20 meters and depth of 450 meters. The uprooted plants include *Terminalia bellerica*, *Phyllanthus emblica*,

Pterocarpus marsupium, *Sweitenia macrophylla*, *Pongamia pinnata*, *Mallotus philippinensis*, *Macaranga peltate* etc. Plants which were shown the greatest survival rate were mainly herbs and shrubs. Very few tree species overcame the disaster. Key species of plants survived are *Apluda mutica* L., *Azadirachta indica* A. Juss., *Cleistanthus collinus* (Roxb.) Benth. ex Hook. f., *Macaranga peltata* (Roxb.) Muell.-Arg., *Mallotus philippensis* (Lam.) Muell.-Arg., *Streblus asper* Lour., *Ziziphus oenoplia* (L.) Mill., etc. This long stretch where elimination of soil and plants occurred created an open space.

Post flood changes in vegetation

The location currently displays a recovery from the effects of outrageous landslide hit which in turn changed the characteristics of vegetation. This is enabled by the primary colonizers such as *Cardiospermum halicacabum* L., *Grewia tilifolia*, *Mitracarpus hirtus* (L.) DC., *Pennisetum polystachyon* (L.), *Senna occidentalis* (L.) Link, *Vernonia cinerea* (L.) Less., and *Vernonia cinerea* (L.) Less.,. Along with these, several invasive species like *Jatropha gossypifolia* L., *Lantana camara* L., *Mikania micrantha* Kunth., are extending their territory across the area. *Lygodium* and *Pityrogramma* are the only identified pteridophytes from the region.

Table 28. Primary Colonizers and Survivors in Vettukad Landslide area

Primary Colonizers	Survivors
<i>Cardiospermum halicacabum</i> L.,	<i>Ailanthus excelsa</i> Roxb.,
<i>Cassia fistula</i> L.,	<i>Apluda mutica</i> L.,
<i>Crotalaria pallida</i> Dryand.	<i>Azadirachta indica</i> A.Juss.
<i>Dipteracanthus prostratus</i> (Poir.) Nees in Wall.,	<i>Calycopteris floribunda</i> Lam.,
<i>Grewia tilifolia</i>	<i>Canthium coromandelicum</i> (Burm. f.) Alston
<i>Hyptis suaveolens</i> (L.) Poit.,	<i>Chromalaena odorata</i> (L.) King & Robins.,
<i>Microstachys chamaelea</i> (L.) Muell.-Arg.,	<i>Cleistanthus collinus</i> (Roxb.) Benth. ex Hook.f.,
<i>Mitracarpus hirus</i> (L.) DC.,	<i>Ficus hispida</i> L. f.,
<i>Oldenlandia corymbosa</i> L.,	<i>Glycosmis pentaphylla</i> (Retz.) DC.,
<i>Pennisetum polystachyon</i> (L.)	<i>Macaranga peltata</i> (Roxb.) Muell.-Arg.
<i>Senna occidentalis</i> (L.) Link,	<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.
<i>Stachytarpheta jamaicensis</i> (L.) Vahl,	<i>Morinda pubescens</i> J. E. Smith
<i>Trema orientalis</i> (L.) Blume	<i>Naregamia alata</i> Wight & Arn.,
<i>Vernonia cinerea</i> (L.) Less.,	<i>Streblus asper</i> Lour.,
	<i>Tectona grandis</i> L. f.
	<i>Ziziphus oenoplia</i> (L.) Mill.,

III.5.2. Alathur Range

Veezhumala (Plates 37-39)

Veezhumala located in the Alathur forest range observed massive landslides in several locations during the heavy rains and resultant flood that shook the state. Three significant landslides at Vaveli and Kattussery accompanied by a number of small mudslides affected the vegetation as well as human life. People were forced to evacuate their homes due to the deposition of soil and falling of uprooted trees.

Vaveli (Plate 37: a-f)

Vaveli is the region located at 10°37'39.205"N and 76°32'9.633"E in an elevation of 358 ft from the sea level. The landslide occurred in 20 meter width and 450m width. *Trema orientalis* and *Helicteres isora* are the major trees uprooted along with numerous herbs and shrubs. The survival rate of plants in this area was relatively low. The area was harbouring a rock pool formed after quarrying earlier, got vanished by the deposition of soil and rocks from the run off after the landslide. This led to the extermination of lower forms, especially aquatic species in the location. *Artocarpus heterophyllus* Lam., and *Borassus flabellifer* L., are the only surviving tree species in this region. The area between a mining location and this affected area is under serious threat. The soil from this area is heavily transported for commercial purpose by soil mining. This may eventually lead to another landslide of even bigger magnitude. Precautions must be taken in order to prevent such a disaster in future in this ecologically sensitive area.

Primary Colonizers

Since there is some trace of water resources are still existing, primary colonizers are thriving efficiently. This includes *Argyreia elliptica* (Roth) Choisy, *Eragrostis tenella* (L.) P. Beauv. ex Roem. & Schult., *Helicteres isora* L., *Hyptis suaveolens* (L.) Poit., *Mitracarpus hirtus* (L.) DC., *Trema orientalis* (L.) Blume etc... *Chromolaena odorata* (L.) King & Robins., and *Lantana camara* L., are the invasive species identified from this area. *Ptyrogramma* is the only pteridophyte surviving in this sector.

Table 29. Primary Colonizers Vizhumala Landslide area

Primary Colonizers in Vaveli
<i>Argyrea elliptica</i> (Roth) Choisy,
<i>Combretum latifolium</i> Blume,
<i>Corchorus aestuans</i> L.,
<i>Crotalaria pallida</i> Dryand.
<i>Croton hirtus</i> L'Herit.,
<i>Eragrostis tenella</i> (L.) P. Beauv. ex Roem. & Schult.
<i>Fioria vitifolia</i> (L.) Mattei,
<i>Helicteres isora</i> L.,
<i>Hibiscus surattensis</i> L.,
<i>Hyptis suaveolens</i> (L.) Poit.,
<i>Ipomoea eriocarpa</i> R. Br.,
<i>Mimosa pudica</i> L.,
<i>Mitracarpus hirtus</i> (L.) DC.,
<i>Passiflora foetida</i> L.,
<i>Pennisetum polystachyon</i> (L.) Schult.,
<i>Phyllanthus amarus</i> Schum. & Thonn.
<i>Themeda triandra</i> Forssk.,
<i>Trema orientalis</i> (L.) Blume
<i>Triumfetta rhomboidea</i> Jacq.,
<i>Urena lobata</i> L.,
<i>Vernonia cinerea</i> (L.) Less.,

Vaveli - Location 2 (Plate 38: a-f)

This location situated at 10°37'30.885N and 76°32'19.633E at an elevation of 492 ft from sea level. The substantial landslide removed soil and plants in 20 meter width and 500 meter depth. *Sterculia urens* is the uprooted tree in this region. This landslide affected households in the lower stretches where soil got deposited. Inclined geography of the region facilitated the movement of soil and rocks in quick pace. Major survivors of this location include *Canthium coromandelicum* (Burm. f.) Alston, *Macaranga peltata* (Roxb.) Muell.-Arg., *Tectona grandis* L. etc. Primary colonizers spread in this location are *Amaranthus spinosus* L., *Canthium coromandelicum* (Burm. f.) Alston, *Digitaria ciliaris* (Retz.) Koeler, *Glycosmis pentaphylla* (Retz.) DC., *Leucas angularis* Benth. in Wall., *Trema orientalis* (L.) Blume, etc. *Chromolaena odorata* (L.) King & Robins., and *Lantana camara* L., are the invasive taxa got distributed widely in this region.

Table 30. Primary colonizers and survivors in Vaveli

Primary Colonizers	Survivors
<i>Alternanthera brasiliana</i> (L.) Kuntze,	<i>Canthium coromandelicum</i> (Burm. f.) Alston
<i>Amaranthus spinosus</i> L.,	<i>Caryota urens</i> L.,
<i>Anamirta cocculus</i> (L.) Wight & Arn.,	<i>Macaranga peltata</i> (Roxb.) Muell.-Arg.
<i>Blumea belangeriana</i> DC.,	<i>Mangifera indica</i> L.,
<i>Canthium coromandelicum</i> (Burm. f.) Alston	<i>Morinda pubescens</i> J. E. Smith
<i>Caryota urens</i> L.,	<i>Tectona grandis</i> L.
<i>Cyperus iria</i> L.,	<i>Trema orientalis</i> (L.) Blume
<i>Digitaria ciliaris</i> (Retz.) Koeler,	
<i>Glinus oppositifolius</i> (L.) A. DC.,	
<i>Glycosmis pentaphylla</i> (Retz.) DC.,	
<i>Hemidesmus indicus</i> (L.) R. Br.	
<i>Hyptis suaveolens</i> (L.) Poit.,	
<i>Leucas angularis</i> Benth. in Wall.,	
<i>Macaranga peltata</i> (Roxb.) Muell.-Arg.	
<i>Mimosa pudica</i> L.,	
<i>Panicum brevifolium</i> L.,	
<i>Scoparia dulcis</i> L.,	
<i>Streblus asper</i> Lour.,	
<i>Trema orientalis</i> (L.) Blume	
<i>Tridax procumbens</i> L.,	
<i>Triumfetta rhomboidea</i> Jacq.,	
<i>Urena lobata</i> L.,	

Kattussery (Plate 39: a-f)

Kattussery is located at latitude 10°37'30.885N and longitude 76°32'39.19526E at an elevation of 522ft from sea level. This landslide is comparatively of lower magnitude but its occurrence inside the rubber plantation caused clearing of trees in a large stretch. This clearing extended up to 400m depth and 10m width. *Macaranga peltata* (Roxb.) Muell.-Arg. and *Trewia nudiflora* L., are the major surviving species of plants. The lower portion of the hill where the landslide occurred is a coconut plantation. This along with the less magnitude of the soil flow enabled the survival of more species. Primary colonizers in this region include *Anamirta cocculus* (L.) Wight & Arn., *Eranthemum capense* L., *Glycosmis pentaphylla* (Retz.) DC., *Mimosa pudica* L., *Pennisetum polystachyon* (L.) Schult., *Urena lobata* L., etc. *Chromolaena odorata* (L.) King & Robins., is the only invasive species identified from the region.

Table 31. Primary colonizers in Kattussery

Primary Colonizers
Anamirta cocculus (L.) Wight & Arn.,
Cyclea peltata (Lam.) Hook. f. & Thoms.,
Eranthemum capense L.,
Ficus hispida L.
Glycosmis pentaphylla (Retz.) DC.,
Macaranga peltata (Roxb.) Muell.-Arg.
Mallotus philippensis (Lam.) Muell.-Arg.
Mimosa pudica L.,
Passiflora foetida L.,
Pennisetum polystachyon (L.) Schult.,
Streblus asper Lour.,
Trema orientalis (L.) Blume
Urena lobata L.,

III.5.3. Nelliampathy Range

Aluvassery - Athavanad, Nemmara (Plate 40. Fig.a-f)

Neliyampathy section of Nemmara forest range has witnessed a drastic change due to land slides caused by floods. The major destruction has happened at 10° 32' 6.4824" N and 76° 37' 16.698" E 43 meter above the sea level. The landslide occurred in a width of 30 meter wide area removing soil upto 300 meter depth. Trees like *Azadiracta indica*, *Hevea brasiliensis*, *Pongamia pinnata* and *Cocos nucifera* were uprooted. Ground vegetation also encountered substantial loss. This includes loss of herbs like *Eclipta prostrata*, *Sida acuta* and *Adathoda vasica*. The devastating landslide completely destroyed four households in the area causing loss of human life also. Most of the under herbs and grasses were completely erased. Rubber plantation in the location lost majority of its trees and has reported reduction of latex production after the flood.

The survivors of flood were primarily large trees like *Bambusa bambos*, *Tectona grandis*, *Cocos nucifera*, *Hevea brasiliensis*, *Phyllanthus emblica*, *Xylia xylocarpa* and *Mangifera indica*. The affected area is significantly got altered in vegetation comparing to adjacent locations especially due to the absence of common plants. Invaders are colonized in

the area after the flood including *Chromolaena odorata*, *Synedrella nodiflora*, *Mimosa pudica*, *Lantana camara*, *Ipomoea hederifolia*, *Ipomoea eriocarpa*, *Ipomoea obscura* and *Mimosa diplotricha*.

Media highlighted the massive loss of habitation and loss of human life in the area during august 2018. The reasons for a massive landslide in this terrain has been explained by way of quarrying activities on the other side of this hillock.

Table 32. Primary Colonizers, Survivors and invaders in Athavanad Landslide area

Primary Colonizers	Invaders
<i>Achyranthus aspera</i> L.,	<i>Chromolaena odorata</i> (L.) King & Robins.,
<i>Alternanthera brasiliana</i> (L.) Kuntze	<i>Cleome viscosa</i> L.
<i>Apluda mutica</i> L.,	<i>Ipomoea eriocarpa</i> R. Br.,
<i>Arundinella mesophylla</i> Nees ex Steud.	<i>Ipomoea obscura</i> (L.)
<i>Azadirachta indica</i> A.Juss.	<i>Ipomoea hederifolia</i> L.,
<i>Cassia fistula</i> L.,	<i>Lantana camara</i> L.,
<i>Centrosema molle</i> Benth.,	<i>Luffa cylindrica</i> (L.)
<i>Clerodendrum infortunatum</i> L.,	<i>Mimosa diplotricha</i> C. Wight ex Sanvalle
<i>Croton hirtus</i> L'Herit.,	<i>Mimosa pudica</i> L.,
<i>Dalbergia sissooides</i> Graham ex Wight & Arn.,	<i>Spilanthes radicans</i> Jacq., Co
<i>Glycosmis pentaphylla</i> (Retz.) DC.,	<i>Synedrella nodiflora</i> (L.) Gaertn.,
<i>Hemidesmis indica</i> (L.) R. Br.	<i>Tridax procumbens</i> L.,
<i>Holarrhena pubescens</i> (Buch.-Ham.) Wall. ex G. Don,	
<i>Hyptis suaveolens</i> (L.) Poit.,	
<i>Indigofera uniflora</i> Buch.-Ham. ex Roxb.	
<i>Mallotus philippensis</i> (Lam.) Muell.-Arg.	
<i>Mitracarpus hirtus</i> (L.) DC.,	
<i>Mollugo oppositifolia</i> (L.) A. DC.,	
<i>Ocimum tenuiflorum</i> L.,	
<i>Pennisetum polystachyon</i> (L.)	
<i>Phyllanthus reticulatus</i> Poir.	
<i>Scoparia dulcis</i> L.,	
<i>Sida acuta</i> Burm. f.,	
<i>Sida cordifolia</i> L.	
<i>Stereospermum colais</i> (Buch.-Ham. ex Dillw.) Mabb.,	
<i>Talinum portulacifolium</i> (Forssk.) Aschers & Schweinf, Weinf.,	
<i>Triumfetta rhomboidea</i> Jacq.,	
<i>Urena lobata</i> L.,	

IV. CONCLUSIONS

The preliminary studies on the landslide hit forest areas in and around Palghat Gap region revealed serious damages to the vegetation uprooting and damaging mostly trees. The ground vegetation experienced washing off in heavy downpour along with top soil. The general observations in all forest ranges were more or less same and the post flood habitat modification has resulted in biological invasion in almost all landslide and mudslide areas.

The habitat features and landslides

The earlier reports of geographical nature of locations where landslides happened states that most of the landslides were in slopes above 22° and most common between 22°–28° slopes. In the present observations also it was confirmed that the areas where landslides or mudslips were happened in inclined planes where the slopes were more or less in the same magnitude.

Majority of the landslide sites were in the fringes of forests, and most of them were in the regions where there is any disruption of the slope continuity by way of ghat road construction, construction of any building etc. This is evident in Nelliampathy hills, where ghat road areas got severe landslides and mudslips. This is an indication that disruption of slope continuity due to forest fragmentation was a major contributing factor to landslides in the district.

Quarrying in vulnerable areas is another contributing factor for landslides in some areas especially Aluvassery in Athavanad in Nemmara region. This has also contributed to the degradations and is reported as a factor that can accelerate landslides in a few locations.

Soil erosion has been reported from most of the forest areas leading to loss of humus and soil nutrients. The erosion of top soil was evident in those areas where there was heavy rain during July – September 2018.

In Kollengode range, heavy landslide in Vazhakundu was at a higher slope where the nearby areas have already been disrupted for construction of resorts for tourism purpose.

Post landslide modifications Vs Primary colonizers and invasives

The uprooting of large trees have reduced up the canopy thickness which resulted in increased light penetration to the under storey. This has resulted in the regeneration of some invasive taxa such as *Lantana camara* L. var. *camara* Antony, *Mikania micrantha* Kunth, *Chromolaena odorata* (L.) King & Robins. along with other taxa such as *Rungia pectinata* (L.) Nees in DC. *Achyranthes aspera* L var. *aspera* Hook., *Pupalia lappacea* (L.) Juss var. *lappacea* Hook., *Elephantopus scaber* L. etc. Since the forest floor is covered by mud and silt, the humus layer got destroyed and this has resulted fast evaporation of the ground water leading to the accelerated drying of the forest floor than their normal drying rate. This lead to the dryness of the forest which will lead to increased forest temperature badly affecting the survival of both flora and fauna. This inturn resulted in higher chances of forest fire in the dry areas of forest ranges especially Walayar forest range. The increased forest fire incidences in many forest areas of the state of Kerala during February and March 2019 can be attributed to this post flood scenario.

In Dhoni hills, the landslides caused changes in the topography and microenvironment resulting in redistribution of several taxa. The availability of moisture and sunlight are primary factors that have influenced the diversity of the emergent vegetation in the landslide affected areas. The loss of canopy cover promoted the profuse growth of several invasive and weedy taxa that thrives in bright sunlight. Also the change in moisture availability caused due to landslide and flooding is responsible for several herbaceous taxa becoming dominant in those areas with high water retention. Short duration herbaceous plants and tuber bearing weak stemmed plants have adapted quickly to the change in the environment and turned out to be primary colonizers in several locations. Plants adapted with quick germinating seeds seem to have an edge over others and equips them to be primary colonizers in the barren regions of the landslide and flood affected areas.

An assessment of the value of loss of habitat and associated floristic elements must be attempted and immediate attention to the biological invasion in forest floor is required, otherwise the long term effects of this post flood scenario in the existing biodiversity will be manifold.

MAJOR FINDINGS

- The landslides, land subsidence or mudslips were happened in inclined planes where the slopes were between 22° – 28° .
- Majority of landslides were in forest fringes where there is disruption of slope continuity
- Disruption of natural habitat by way of any type of construction – resort, road, bridges etc.
- The ground vegetation experienced washing off in heavy downpour along with top soil.
- Serious damages to vegetation especially trees, by way of uprooting
- The post flood habitat modification has resulted in biological invasion in almost all landslide and mudslide areas
- The primary colonizers are invaders with high ecological amplitude like *Mikania*, *Lantana*, *Chromolaena* etc.
- The loss of canopy cover promoted the profuse growth of several invasive and weedy taxa that thrives in bright sunlight
- Increase in forest fire in February – March 2019
- Excess drying up of ground vegetation
- Quarrying in vulnerable areas is one of the contributing factors for landslides
- Heavy loss to plantations of Tea, coffee, Coconut, arecanut, Teak and Rubber due to land slides, land subsidence and mud slides owing to heavy downpour
- The loss for Plantain and Rice in the district due to landslides and associated flood
- The major forest trees affected are *Grewia tiliifolia*, *Ficus* sp., *Cullenia*, *Homonoia*, *Macaranga*, *Mallotus* and *Bauhinia racemosa*.
- Habitat loss to significant taxa such as *Exacum tetragonum*, *Swertia angustifolia*, *Sonerila nairii*, *Canscora perfoliata* and *Colebrookea oppositifolia*.
- Loss of habitat for endemics such as *Crepidium resupinatum*, *Arisaema leschenaultia*, *Alpinia malaccensis*, *Biophytum intermedium* etc.

GAP AREA

The quick survey of post flood habitat modification could generate a primary data on what has actually happened in the forest areas due to land slips, land subsidence and mud slides. As the nature herself show resilience to almost all natural catastrophes, continuous monitoring of landslide areas only could confirm whether the taxa got washed off is tolerant and will reappear after the monsoon. The studies must also be conducted to assess which all taxa must be reintroduced in such areas where the canopy got opened. After heavy rains in August 2018, almost all districts of the state experienced high temperature with heat waves in March April 2019. The effect of the same on vegetation must also be monitored in comparison with the flood effect.

RECOMMENDATIONS

- Steps may be taken to eliminate the invading taxa in land slide hit areas of the district
- Eco-restoration programmes with resilient taxa must be initiated in the damaged forest areas
- Reforestation programmes must be initiated with location based taxa that got disrupted
- Strict laws must be formulated to control any type of construction, viz. forest roads, bridges, resorts for tourists in forest areas
- Inter departmental collaboration between the authorities of Disaster Management, Pollution control, Biodiversity conservation, water and dam management, Tourism, forests and mining and geology is essential for the effective eco-restoration planning.

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