

KERALA STATE
BIODIVERSITY BOARD

A CONCISE REPORT ON BIODIVERSITY LOSS DUE TO 2018 FLOOD IN KERALA

(IMPACT ASSESSMENT CONDUCTED BY KERALA STATE BIODIVERSITY BOARD)

Editors: Dr. S.C. Joshi IFS (Rtd.), Dr. V. Balakrishnan, Dr. N. Preetha






A CONCISE REPORT ON BIODIVERSITY LOSS DUE TO 2018 FLOOD IN KERALA

(Impact assessment conducted by Kerala State Biodiversity Board)

Editors
Dr. S.C. Joshi IFS (Rtd.), Dr. V. Balakrishnan, Dr. N. Preetha

Editorial Board

Dr. K. Satheeshkumar
Sri. K.V. Govindan
Dr. K.T. Chandramohanan
Dr. T.S. Swapna
Sri. A.K. Dharni IFS

Published By

Member Secretary
Kerala State Biodiversity Board

ISBN: 978-81-934231-3-4

Design and Layout
Dr. Baijulal B

A CONCISE REPORT ON BIODIVERSITY LOSS DUE TO 2018 FLOOD IN KERALA

(Impact assessment conducted by Kerala State Biodiversity Board)

EDITORS

Dr. S.C. Joshi IFS (Rtd.)
Dr. V. Balakrishnan
Dr. N. Preetha

Kerala State Biodiversity Board

PINARAYI VIJAYAN
CHIEF MINISTER

GOVERNMENT OF KERALA

Secretariat
Thiruvananthapuram-695 001

No.30 (3)/Press/CMO/2020. 06th January, 2020.

MESSAGE

The Kerala State Biodiversity Board in association with the Biodiversity Management Committees - which exist in all Panchayats, Municipalities and Corporations in the State - had conducted a rapid Impact Assessment of floods and landslides on the State's biodiversity, following the natural disaster of 2018.

This assessment has laid the foundation for a recovery and ecosystem based rejuvenation process at the local level. Subsequently, as a follow up, Universities and R&D institutions have conducted 28 studies on areas requiring attention, with an emphasis on riverine rejuvenation.

I am happy to note that a compilation of the key outcomes are being published. I congratulate the KSBB, all the BMCs, Universities and R&D institutions for making this possible. I hope that it will enable the realisation of a "Nava Keralam', which is biodiversity inclusive.

My best wishes.

Pinarayi Vijayan

Tel: (0471) 2333812 & 2333682 Fax: (0471) 2333489 e-mail : chiefminister@kerala.gov.in
website : www.keralacm.gov.in

Dr. USHA TITUS IAS
PRINCIPAL SECRETARY

Higher Education & Environment Dept.
Government of Kerala, Secretariat
Thiruvananthapuram-695 001
Phone-Office : 0471-2331509
0471-2518997
E-mail : secy.hedu@kerala.gov.in

Date 05.02.2020

MESSAGE

In the wake of the 2018 and 2019 floods, Kerala's vulnerability to natural disasters is the subject of study by various research organisations, Kerala Government has established the Rebuild Kerala Initiative to build ecological and technical safeguards with the main objective of "Building Back Better". Protection of environmentally fragile areas, coastal lands and low lying lands is a key priority.

Kerala State Biodiversity Board commissioned several studies and the book is a compilation of the salient findings of these studies. I am sure that the results of these studies will enable to lay the foundation for ecosystem based recovery programme. I hope the Biodiversity Management Committees established at local level will take the lead in this.

Dr. Usha Titus

Foreword

A diverse ecosystem is more resilient to Climate Change. Thus while 2011-20 was declared as the UN decade on Biodiversity, 2021-30 has been declared as UN decade on Ecosystem restoration. Ecosystem restoration is fundamental to achieving the Sustainable Development Goals, mainly those on climate change, poverty eradication, food security, water and biodiversity conservation. The UN Decade on Ecosystem Restoration unites the world behind a common goal: preventing, halting and reversing the degradation of ecosystems worldwide. Forests, grasslands, croplands, wetlands, savannahs, and other terrestrial to inland water ecosystems, marine and coastal ecosystems and urban environments—all of them are in dire need of some level of protection and restoration. Nature-based solutions to restoration range from protecting natural areas to increasing the genetic diversity of trees to increase forest resilience, to making cities greener. Unsustainable human activities, from farming and mining to industry, infrastructure and tourism, are degrading the diverse ecosystems of Kerala with negative impacts on biological diversity and peoples' livelihoods. The natural disasters which Kerala witnessed shall be taken up as a wakening up call and there has never been a more urgent need to restore damaged ecosystems than now. The Government of Kerala through the Rebuild Kerala Development Plan is seeing the reconstruction as an opportunity to build back better through a people inclusive programme. The key outcomes of this study include prioritization of areas for recovery measures at Periyar, Pampa, Bharatapuzha and Chalakudy river basin and prioritization of riparian species for ecorestoration. The results of the study were shared with the respective BMCs and I hope that the BMCs will learn from the major findings of these studies and implement the recommendations locally.

Dr. S.C. Joshi IFS (Rtd.)

Chariman

Preface

Kerala State Biodiversity Board in association with Biodiversity Management Committee's conducted a Rapid Impact Assessment of flood/ landslides on Biodiversity during 2018. It is for the first time in India that such an assessment of impact of natural disasters on Biodiversity was conducted at LSG level incorporating community perspectives of the affect on Biodiversity and Ecosystems. The report submitted to Government included impact on species both flora and fauna and ecosystems. Major causes of disaster according to community includes Land use change in wetlands, Removal of river bank vegetation, Construction activities in hill slopes, Unsustainable quarrying etc. As a follow-up to this areas requiring attention were prioritized and 28 studies related to assessment of impact of floods/ landslides on Biodiversity and ecosystem were awarded to R & D institutions and Universities. The studies included Impact of natural disasters on riparian vegetation of nine rivers, four studies relating to tribal livelihood, eight relating to flora, three relating to fauna, one relating to Agriculture, two relating to forest ecosystems and two relating to mangrove ecosystems. The present book is a compilation of the salient findings and recommendations of the studies.

I wish to thank all the institutes/ NGOs who have undertaken this work in a time bound manner.

Dr. V. Balakrishanan
Member Secretary

CONTENT

List of Research Team

1 Dr. BabuAmbat and Dr. Sabu T., Centre for Environment and Development , Thiruvananthapuram

2 Dr. Sarita G. Bhat and Dr. Sreekanth P.M. Department of Biotechnology, KUSAT, Kochi

3 Dr. P.O. Nameer, Professor & Head (Wildlife) & The Dean of the Academy of Climate Change Education (ACCER), KAU, Thrissur.

4 Dr. Rajeev Raghavan, Asst. Professor, Dept. of Fisheries Resource Management, KUFOS, Kochi.

5 Dr. Renjan Mathew, State Director, WWF-India, Thiruvananthapuram,

6 Dr. Maya C. Nair, Assistant Professor, Post Graduate & Research Department of Botany, Govt. Victoria College, Palakkad.

7 Dr. N. S. Pradeep, Senior Scientist, KSCSTE-Malabar Botanical Garden and Institute for Plant Sciences, Kozhikode.

8 Dr. R. Prakash Kumar and Dr. Deepu Sivadas, JNTBGRI, Thiruvananthapuram.

9 Dr. K.G. Padmakumar, Director, International Research and Training centre for Below Sea level Farming (IRTCBSF), Alappuzha.

10 Dr. Sreekumar V.B., Kerala Forest Research Institute, Peechi, Thrissur.

11 Dr. F.G. Benno Pereira, Assistant Professor, Dept. of Zoology, University of Kerala, Kariavattom, Trivandrum.

12 Dr. Shiburaj S., JNTBGRI, Thiruvananthapuram,

13 Dr. P.M. Radhamany, Professor, Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram

14 Dr. Jitesh Krishnan R, Asst. Professor, Dept of Botany, NSS, College, Pandalam, Patahanamthitta.

15 Dr. M. Rajendraprasad, Scientist, JNTBGRI, Thiruvananthapuram,

16 Dr. Suhara Beevy S., Associate Professor & Head, Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram

17 Dr. M.G. Sanal Kumar, Asst. Professor and Research Department of Zoology, NSS College, Pandalam, Patahanamthitta.

18 Dr. N. Shibin Mohanan, Asst. Professor and FLAIR - Kerala Faculty
Nirmala College, Department of Botany, Muvattupuzha

19 Dr. Jose Mathew, Asst. Professor, Department of Botany, SD College, Alappuzha.

20 Dr. Sarita G. Bhat and Dr. Bindiya E.S., Department of Biotechnology, CUFOS, Kochi.

21 Dr. G. Suresh and Dr. A Satheesan, Principal Coordinator, CMD, Thiruvananthapuram.

22 T.R. Suma, Scientist, Community Agro-biodiversity Centre, MSSRF, Wayanad.

23 Dr. S. Sreekumar and Dr. K.K. Seethalekshmi, IRTC, Integrated Rural Technology Centre (IRTC), Mundur, Palakkad.

24 Dr. Amitha Bachan K.H., Assistant Professor & Research Guide, Department of Botany, MES Asmabi College, Thrissur.

25 Dr. Suresh V. Assistant Professor, Dept. of Botany, Govt. Victoria College, Palakkad.

26 Dr. Richard Scaria, Assistant Professor, Dept. of Geography, Govt. College,Chittur, Palakkad.

27 Dr. G. Suresh, Project Director, CMD, Thiruvananthapuram.

28 Dr. E.A. Siril. Associate Professor, Dept. of Botany, University of Kerala, Kariavattom Campus, Thiruvananthapuram.

List of Tables

List of Figures

INTRODUCTION

The state of Kerala is in between Arabian Sea and the Western Ghats. Though the state is blessed with rich biodiversity areas including the Western Ghats, our state has been identified as most vulnerable to flood due to its geographical pattern together with the injudicious anthropogenic activities. After a historical catastrophic flood in July 1924, the terrain of the state was drastically affected and which was further intensified through unscientific activities that also contributed to the vast toll of living beings including subsoil microorganisms during the last 2018 flood in Kerala.

According to Kerala State Disaster Management (KSDMA) (2016), nearly 14.5% of the state land area is prone to flood. Landslides are the major hazard in the state especially in areas that are close proximity to the Western Ghats in Wayanad, Kozhikode, Idukki and Kottayam districts.

In order to understand the impact of 2018 flood on biodiversity loss, the Kerala State Biodiversity Board had conducted a rapid impact assessment with the support of respective BMCs. It was recorded that 771 landscapes including riverine, forest, plantations and agriculture fields were severely affected due to the 2018 flood. Available data with respect to loss of species revealed that approximately 287 varieties of agricultural crops, 1053 flora and 695 fauna were either lost or exiled.

Based on the preliminary observation, huge loss of biodiversity in the areas where flood affected might be due to changes in the habitats, change in land use mainly wetlands, construction activities in hill slopes, removal or diversion of river flow, unwise granite extraction etc..

Being a facilitating body, the KSBB has taken up the assignment to develop appropriate follow-up action for the Rejuvenation of Rivers in the flood affected areas for which 28 projects have been awarded to different R&D Institutions and academic centres in the state of Kerala.

The studies covered the following aspects

I: Impact of Natural Disasters on Terrestrial and Aquatic ecosystem

1. Impact of natural disasters on Terrestrial ecosystem in high ranges of Kerala Wayanad, Palghat (Palghat gap area, Nelliampathy, Attapady), Idukki and Thrissur (Athirapally)
2. Impact of flood on riverine vegetation of Pamba, Periyar, Chalakudy, Bharathapuzha, Kallai, Chaliyar, Achenkovil, Manimala, Korapuzha and Kuttiyadi river.
3. Impact of flood on Mangrove ecosystem of Mangalavanam, Pathiramanal, Pallipuaram, Perumbalam.
4. Impact of flood on selected faunal species
5. Impact of flood on Soil biota of Pamba, Periyar and Chalakudy.
6. Impact of landslides and flood on Tribal livelihood in Attapady and Athirapally.
7. Impact of flood on Agriculture- Alappuzha (Kuttanad) and Wayanad.
8. Flood and Spread of Invasive species

II: Strategies and Action Plan for Ecorestoration

III: Annexures

IMPACT OF NATURAL DISASTERS ON TERRESTRIAL AND AQUATIC ECOSYSTEM

1 IMPACT OF NATURAL DISASTERS ON TERRESTRIAL ECOSYSTEM IN HIGH RANGES OF KERALA - WAYANAD, PALGHAT, IDUKKI, THRISSUR.

Majority of mass movements in Kerala occur in hill slopes along the Western Ghats. About 8% of area in The Western Ghats of Kerala is classified as critical zone for mass movements. Shallow landslides and debris flows are more common than deep seated ones. Almost all mass movements occur during monsoon indicating that the main triggering mechanism is pore pressure variations as a result of the combination of prolonged and high intensity rainfall. Piping is also a major intrinsic contributor to landslide initiation in the region. Landslides in the past, were probably confined to rainfall intensities of extreme return intervals. The intensity of landslides is observed to have increased since the population expansion in the late 19th century. This is accelerated by anthropogenic activities such as forest clearing, deforestation, construction activities, blocking stream flow and crop cultivation in steeps. Developmental activities also resulted in the blocking of natural drainage resulting in excess surface drainage during high intensity downpour.

1. 1. WAYANAD

Wayanad district experienced highest rainfall during the month of May–August 2018. In the month of July, total rainfall increased by 160% from the previous two years; in the month of August there has been an increase in total rainfall of 142 % and 263 % from 2017 and 2016 respectively. It has been observed that the areas around Lakkidi, Vythiri, Vellaramkunnu, Pozhuthana, Koroth, Arimala and Periya experiences the highest rainfall of 3,322.96–3,774.33 mm. The eastern parts of the district experiences comparatively low rainfall in the range 1,823.48–2,274.85 mm.

The major landslide affected areas correlates with the spatial distribution of rainfall over the district. The rainfall data from four IMD stations in Wayanad shows that during June and July, Vythiri recorded the highest amount of rainfall with 1380.5 mm and 1500 mm over last years 646.2mm and 565.7mm respectively. Mananthavady recorded 1420.6mm during August higher than 1294.6mm recorded in Vythiri

Wayanad has a unique topography and microclimatic condition as it is evident from its rich biodiversity. About 2034 species of angiosperms are known from the region with 29% endemics. The district is also rich in pteridophyte diversity with 163 species including 19 endemics. The high degree of endemism reflects the uniqueness of this region. As part of the study a macro landslide hazard zonation mapping using 14 factors on 1:50,000 scale of Wayanad district was prepared. Rainfall distribution, drainage density, Elevation, Slope, Lineament density, Landuse, Soil, Landform, TWI and TPI were some of the parameters used. The landslide susceptibility map was derived using a weighted overlay method depending on its influence on landslide occurrence and categorized into five susceptibility class: very low, low, moderate, high and very high.

MAJOR FINDINGS

1. The total area under forests in Wayanad is 787 square kilometers. The rapid assessment inventoried 60 major and 56 minor slope movements degrading over 50 hectares of forest area leading to a loss of forest cover. The most number of slope movements occurred in Wayanad South division with 64 instances and 51 were recorded in Wayanad North division. 25 appears to be deep seated landslides due to excessive soil water pressure.
2. Landslides/slips had occurred mostly in the Wayanad North and South Forest divisions and there are no such instances under the forest areas of Wayanad Wildlife Sanctuary.
3. The incidences of landslides can be grouped topographically into two areas - Vythiri mountain belt and Makkimala belt, which have areas with inherently unstable slopes.
4. The results revealed that in the district 7.98 % area is under very high-risk class, 17.99% under high-risk class which totals 25.97% equalling to 536.22 km^2 land area.
5. A panchayat level analysis showed that more than 70% area of Meppadi, Vythiri, Pozhuthana, Thariyode, Padinjarathara, Thondernadu and 50% area of Thavinjal and Tirunelli falls under very high- and high-risk zones.
6. Fissures in earth and cases of land subsidence were seen in Brahmagiri, Plamoola, Priyadarshini estate and forest areas. Landslides in Brahmagiri, Peedikapullu, Sooryamudi had also affected the grasslands as these occurred in the confluence of forest and grassland. Soil-stripping by landslides largely reduced the productivity in these areas.
7. Inmajorlandslide-hitareaslikePeedikapullu,Panamkunduchal,Arikallammottamchal, Muthumari, Kambamala slumps and earth flows caused low-level, long-term contributions of sediment and large woody debris to channels; partial channel blockages; local channel constriction below the point of landslide entry; and shifts in channel configuration. It also led to the closure of several springs.
8. Debris flow wiped out vegetation and wildlife in its path. This has also affected the soil seed bank of this region and the soil microbiota.
9. Debris flow has uprooted several large trees causing an opening of the closed canopies inducing a gap effect. When one or a few canopy trees die (or are injured) in a forest, small opening - 'gaps,' are formed in the forest canopy and are then filled

with other trees. The gaps created thus provide microenvironmental conditions (light, moisture or temperature), favouring the establishment of shade-intolerant species.

10. Studies have shown that much of the climax species found in the Western Ghats are having recalcitrant seeds. Adding to this since some slides are close to forest margins, there is an increased chance of establishment of invasive species which is already evident as the presence of 45 species which are known for their invasive nature was documented and this could suppress the establishment of other species.
11. The landslides caused severe damage to the forest by removing topsoil, blocking springs and increasing downstream sedimentation. Several 3rd and 4th order streams in Vythiri mountain belt and Makkimala—Tirunelli belt were severely damaged.
12. In places like Kurisukuthi, Maniyankunnu, Kambamala, Muthumari large evergreen patches have been damaged thereby effecting the microhabitat conditions in these regions.
13. A population loss of 376 angiosperm and 21 pteridophyte species was estimated. Of these fourteen angiosperm and five pteridophytes fall under different threat categories. A total of 81 Angiosperm of which 40 species are endemic to the southern Western Ghats and another 23 to the Western Ghats and 4 Pteridophyte species endemic to the Indian mainland suffered population loss. As a whole a total of 527 species of high conservation value has been affected.
14. Of the angiosperm species suffered the population loss 46 where sourced as NWFP and 200 has known medicinal properties.
15. *Vateria indica* L. a critically endangered species suffered major population loss. By direct volume measurement of the trunks, it is estimated that about 5,958.651 m3 of wood of this species has been lost as part of the landslides. The other vulnerable species includes *Casearia wynadensis, Cinnamomum sulphuratum, Hydnocarpsu pentandrus, Myristica malabarica, Ochreinanculea missionis, Orophea uniflora, Shorea roxburghii,* endangered species as *Hopea ponga, Kingiodendra pinnatum, Dysoxylum malabaricum* etc. These along with other endemics which suffered population loss should be under priority on further recovery and restoration activities.
16. The other species suffering the most are *Aglaia barberi, Apodytes dimidiata* , *Bischofia javanica* , *Canarium strictum* , *Cinnamomum malabatrum*, *Elaeocarpus tuberculatus*, *Lagerstroemia microcarpa* , *Macaranga peltata, Olea dioica* , *Palaquium ellipticum*, *Reinwardtiodendron anamalaiense* , *Schleichera oleosa* , *Symplocos cochinchinensis* ssp. *laurina, Symplocos racemosa* etc.
17. A marked variation in the flowering phenology of several high-altitude species has been observed due to the change in rainfall pattern. Some species like *Phyllanthus emblica* L., *Toddalia asiatica, Wendlandia thyrsoidea, Ziziphus rugosa* etc. showed a delay in the onset of flowering. While some others like *Cinnamomum sulphuratum, Diospyros nilagirica* , *Elaeocarpus variabilis* etc. showed early flowering.
18. During this summer the spread of forest fire was found to be double the area than last year which can be due to the change in drainage regime along with the increase in summer temperature.
19. A total of 45 invasive species was identified during the rapid assessment.
20. 31 species prioritized for ecorestoration.

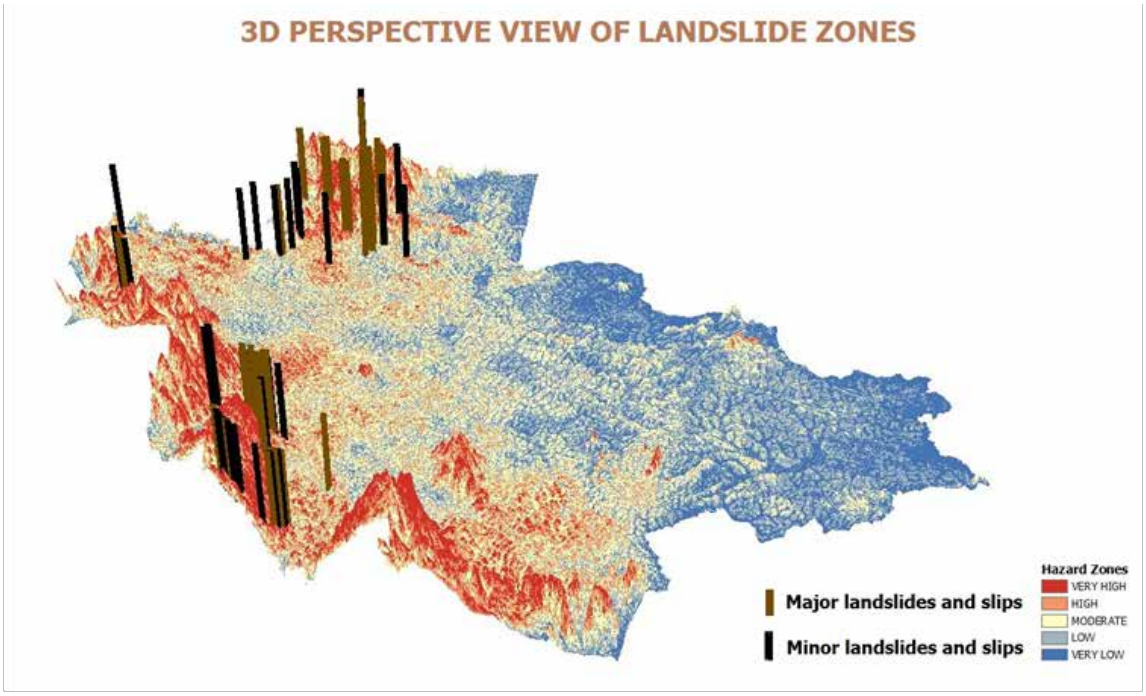

Fig 1. 3D Perspective view of Landslide zone- Wayanad

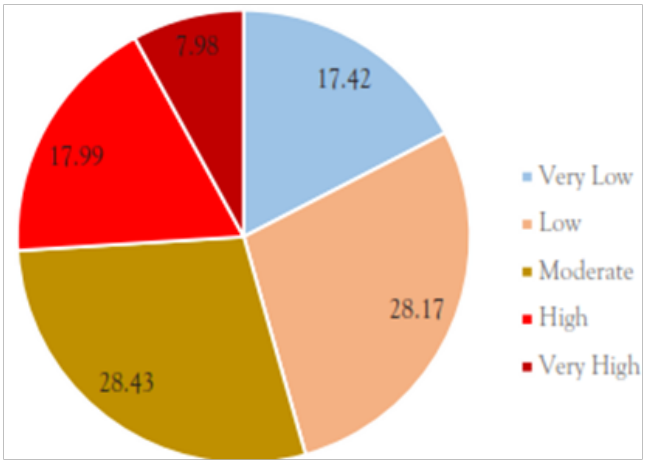

Fig 2. Percentage area falling under each Hazard class- Wayanad

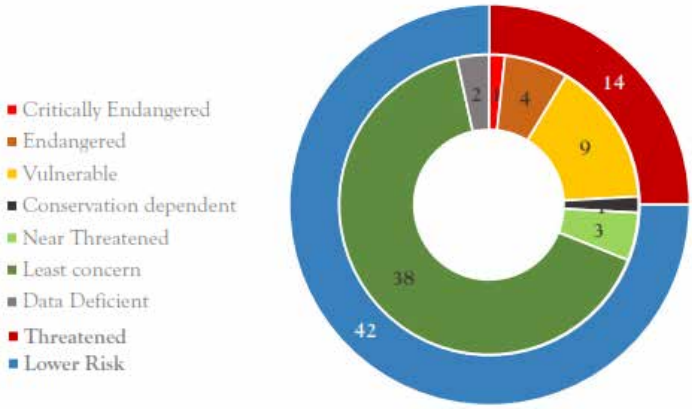

Fig 3.Conservation status of Species- Wayanad

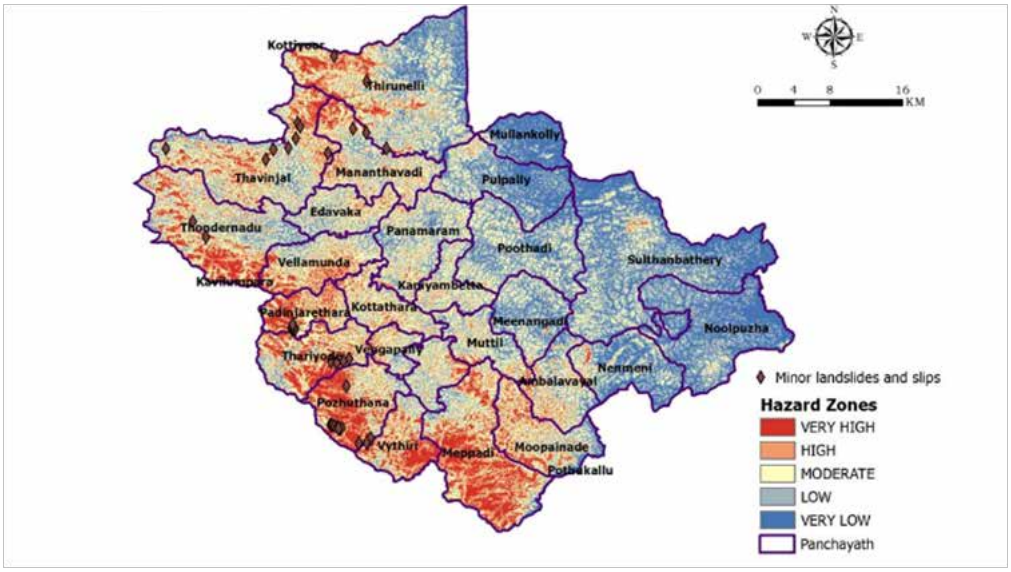

Fig 4. Minor landslide sites overlaid on Landslide Hazard Zonation Map of Wayanad

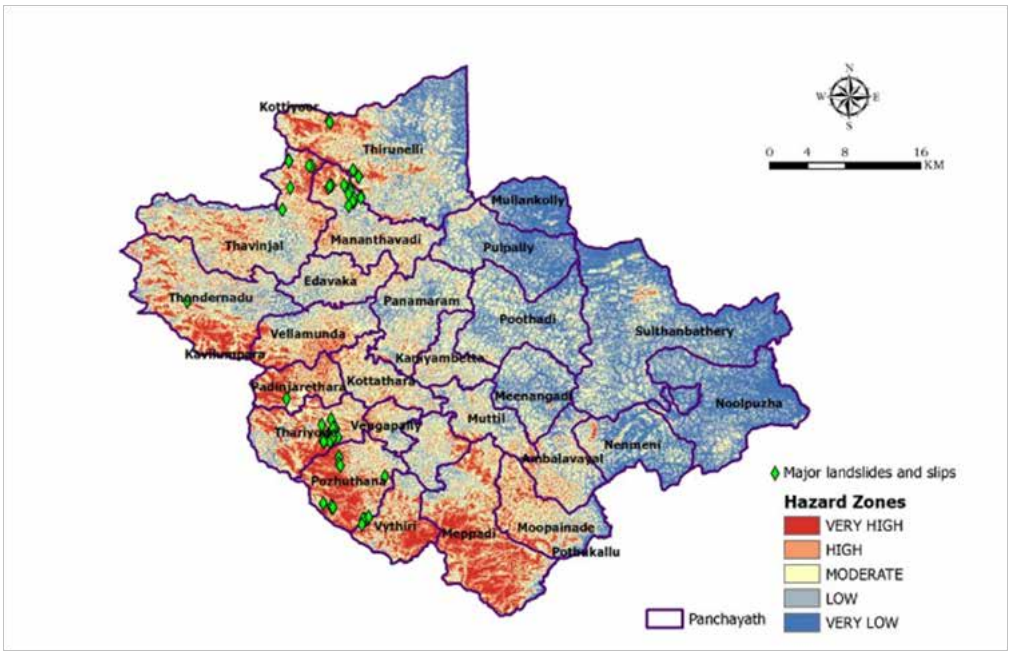

Fig 5. Major landslide sites overlaid on Landslide Hazard Zonation Map of Wayanad

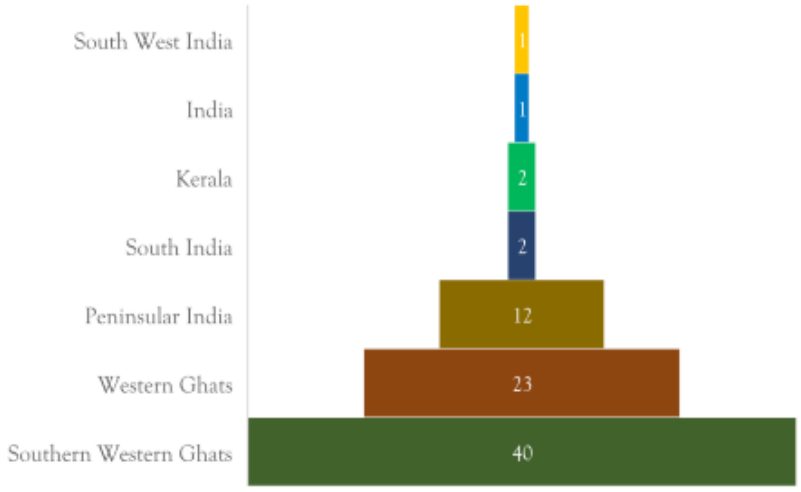

Fig 6. Number of Endemic species suffered population loss- Wayanad

Table 1. Endemic species that suffered population loss in Wayanad

Sl. No.	Species	Family	Endemic to
1	*Actinodaphne bourdillonii* Gamble	Lauraceae	Southern Western Ghats
2	*Actinodaphne malabarica* Balakr.	Lauraceae	Southern Western Ghats
3	*Aeschynanthus perrottetii* A.DC.	Gesneriaceae	Western Ghats
4	*Aglaia barberi* Gamble	Meliaceae	Southern Western Ghats
5	*Allophylus concanicus* Radlk.	Sapindaceae	Western Ghats
6	*Ancistrocladus heyneanus* Wall. ex Graham	Ancistrocladaceae	Western Ghats
7	*Apollonias arnottii* Nees	Lauraceae	Southern Western Ghats
8	*Archidendron monadelphum* (Roxb.) Nielson *var. gracile* (Bedd.) Sanjappa	Mimosaceae	Southern Western Ghats
9	*Artocarpus hirsutus* Lam.	Moraceae	Southern Western Ghats
10	*Arundinella ciliata* (Roxb.) Nees ex Miq.	Poaceae	Peninsular India
11	*Bauhinia phoenicea* Wight & Arn.	Caesalpiniaceae	Western Ghats
12	*Bridelia stipularis* (L.) Bl.	Euphorbiaceae	Peninsular India
13	*Calophyllum calaba* L.	Clusiaceae	Southern Western Ghats
14	*Capparis cleghornii Dunn ex Gamble*	Capparaceae	South India
15	*Casearia wynadensis Bedd.*	Flacourtiaceae	Southern Western Ghats (Kerala)
16	*Chionanthus courtallensis Bedd.*	Oleaceae	Southern Western Ghats
17	*Chionanthus mala-elengi (Dennst.) P. S. Green*	Oleaceae	Peninsular India
18	*Cinnamomum malabatrum (Burm. f.) Blume*	Lauraceae	Southern Western Ghats
19	*Cinnamomum sulphuratum Nees*	Lauraceae	Western Ghats
20	*Clausena austroindica Stone & K.N. Nair*	Rutaceae	Southern Western Ghats
21	*Cullenia exarillata Robyns*	Bombacaceae	Southern Western Ghats
22	*Derris brevipes (Benth.) Baker*	Fabaceae	Western Ghats
23	*Dillenia bracteata Wight*	Dilleniaceae	Western Ghats
24	*Diospyros pruriens Dalz.*	Ebenaceae	Western Ghats
25	*Dipterocarpus indicus Bedd.*	Dipterocarpaceae	Western Ghats
26	*Drypetes venusta (Wight) Pax & Hoffm.*	Euphorbiaceae	Southern Western Ghats
27	*Dysoxylum malabaricum Bedd. ex Hiern*	Meliaceae	Southern Western Ghats
28	*Elaeocarpus munronii (Wight) Mast.*	Elaeocarpaceae	Southern Western Ghats
29	*Ensete superbum (Roxb.) Cheesman*	Musaceae	Peninsular India
30	*Eriocaulon conicum (Fyson) C.E.C. Fisch.*	Eriocaulaceae	Peninsular India
31	*Eugenia argentea Bedd.*	Myrtaceae	Southern Western Ghats
32	*Flacourtia montana Graham*	Flacourtiaceae	Western Ghats

33	*Garcinia rubro-echinata Kosterm.*	Clusiaceae	Western Ghats
34	*Holigarna arnottiana Hook. f.*	Anacardiaceae	Southern Western Ghats
35	*Humboldtia brunonis Wall.*	Caesalpiniaceae	Southern Western Ghats
36	*Hydnocarpus pentandra (Buch.-Ham.) Oken*	Flacourtiaceae	Western Ghats
37	*Ixora elongata Heyne ex G. Don*	Rubiaceae	Endemic to India
38	*Kingiodendron pinnatum (Roxb. ex DC.) Harms*	Caesalpiniaceae	Southern Western Ghats
39	*Knema attenuata (Hook. f. & Thoms.) Warb.*	Myristicaceae	Western Ghats
40	*Lagerstroemia microcarpa Wight*	Lythraceae	Western Ghats
41	*Litsea beddomei Hook. f.*	Lauraceae	Southern Western Ghats
42	*Litsea bourdillonii Gamble*	Lauraceae	Southern Western Ghats
43	*Litsea coriacea (Heyne ex Meisner) Hook. f.*	Lauraceae	Peninsular India
44	*Litsea mysorensis Gamble*	Lauraceae	South India
45	*Luvunga eleutherandra Dalz.*	Rutaceae	Western Ghats
46	*Meiogyne pannosa (Dalz.) Sinclair*	Annonaceae	Western Ghats
47	*Meiogyne ramarowii (Dunn) Gandhi*	Annonaceae	Southern Western Ghats
48	*Memecylon randerianum SM & MR Almeida*	Melastomataceae	Southern Western Ghats
49	*Mitragyna tubulosa (Arn.) Hav.*	Rubiaceae	Peninsular India
50	*Myristica malabarica Lam.*	Myristicaceae	Western Ghats
51	*Nothopegia racemosa (Dalz.) Ramam.*	Anacardiaceae	Western Ghats
52	*Oberonia brachyphylla Blatt. & McCann*	Orchidaceae	Southern Western Ghats
53	*Ochlandra travancorica (Bedd.) Benth. ex Gamble*	Poaceae	Southern Western Ghats
54	*Ochreinauclea missionis (Wall. ex G. Don)Ridsd.*	Rubiaceae	Southern Western Ghats
55	*Orophea malabarica Sasidh. & Sivar.*	Annonaceae	Southern Western Ghats
56	*Orophea uniflora Hook. f. & Thoms.*	Annonaceae	Southern Western Ghats
57	*Palaquium ellipticum (Dalz.) Baill.*	Sapotaceae	Western Ghats
58	*Pandanus canaranus Warb.*	Pandanaceae	Peninsular India
59	*Phaeanthus malabaricus Bedd.*	Annonaceae	Southern Western Ghats
60	*Poeciloneuron indicum Bedd.*	Clusiaceae	Western Ghats
61	*Pogostemon purpurascens Dalz.*	Lamiaceae	South-West India
62	*Polyalthia fragrans (Dalz.) Bedd.*	Annonaceae	Southern Western Ghats
63	*Psychotria flavida Talbot*	Rubiaceae	Peninsular India
64	*Pterospermum rubiginosum Heyne ex Wight & Arn.*	Sterculiaceae	Southern Western Ghats

65	*Reinwardtiodendron anamalaiense (Bedd.)Mabb.*	Meliaceae	Southern Western Ghats
66	*Salacia fruticosa Heyne ex Lawson*	Hippocrateaceae	Western Ghats
67	*Semecarpus auriculata Bedd.*	Anacardiaceae	Southern Western Ghats
68	*Smilax wightii A. DC.*	Smilacaceae	Southern Western Ghats
69	*Strobilanthes barbatus Nees*	Acanthaceae	Western Ghats
70	*Strobilanthes ciliatus Nees*	Acanthaceae	Southern Western Ghats
71	*Strobilanthes lupulinus Nees*	Acanthaceae	Peninsular India
72	*Strobilanthes rubicundus (Nees) Anders*	Acanthaceae	Southern Western Ghats
73	*Swertia lawii (Wight ex Clarke) Burkill*	Gentianaceae	Southern Western Ghats
74	*Symplocos wynadense (O. Ktze.) Nooteb.*	Symplocaceae	Southern Western Ghats
75	*Syzygium laetum (Buch.-Ham.) Gandhi*	Myrtaceae	Southern Western Ghats
76	*Tabernaemontana gamblei Subram. & Henry*	Apocynaceae	Southern Western Ghats
77	*Terminalia paniculata Roth*	Combretaceae	Peninsular India
78	*Themeda cymbaria (Roxb.) Hack.*	Poaceae	Peninsular India
79	*Thunbergia mysorensis (Wight) Anders.*	Acanthaceae	Western Ghats
80	*Vateria indica L.*	Dipterocarpaceae	Southern Western Ghats
81	*Xanthophyllum arnottianum Wight*	Xanthophyllaceae	Southern Western Ghats

Table 2. List of NTFPs suffered population loss-Wayanad

Sl. No.	Species	Family	Part used
1	*Acacia caesia (L.) Willd.*	Mimosaceae	Bark
2	*Ailanthus triphysa (Dennst.) Alston*	Simaroubaceae	Resin
3	*Alstonia scholaris (L.) R. Br.*	Apocynaceae	Bark
4	*Anamirta cocculus (L.) Wight &Arn.*	Menispermaceae	Seed
5	*Aphanamixis polystachya (Wall.) Parker*	Meliaceae	Bark
6	*Areca catechu L.*	Arecaceae	Fruit
7	*Asparagus racemosus Willd.*	Liliaceae	Root
8	*Biophytum intermedium Wight*	Oxalidaceae	Entire plant
9	*Boerhavia diffusa L.*	Nyctaginaceae	Root
10	*Cinnamomum malabatrum (Burm. f.) Blume*	Lauraceae	Bark
11	*Cinnamomum sulphuratum Nees*	Lauraceae	Bark
12	*Cyclea peltata (Lam.) Hook. f. & Thoms.*	Menispermaceae	Root
13	*Dysoxylum malabaricum Bedd. ex Hiern*	Meliaceae	Bark
14	*Elettaria cardamomum (L.) Maton*	Zingiberaceae	Fruit
15	*Embelia ribes Burm. f.*	Myrsinaceae	Fruit
16	*Entada rheedei Spreng.*	Mimosaceae	Seed

17	*Ficu sracemosa L.*	Moraceae	Bark
18	*Garcinia gummi-gutta (L.) Robs.*	Clusiaceae	Fruit
19	*Gmelina arborea Roxb.*	Verbenaceae	Root
20	*Helicteres isora L.*	Sterculiaceae	Fruit
21	*Hellenia speciosa (J. Koenig) Govaerts*	Costaceae	Root
22	*Hemidesmus indicus (L.) R. Br.*	Asclepiadaceae	Root
23	*Hydnocarpus pentandra (Buch.-Ham.) Oken*	Flacourtiaceae	Fruit
24	*Kingiodendron pinnatum (Roxb. ex DC.) Harms*	Caesalpinaceae	Wood oil
25	*Mesua ferrea L.*	Clusiaceae	Flowers & Seeds
26	*Naregamia alata Wight & Arn.*	Meliaceae	Root
27	*Palaquium ellipticum (Dalz.) Baill.*	Sapotaceae	Seed
28	*Persea macrantha (Nees) Kosterm.*	Lauraceae	Bark
29	*Phoenix loureiroi Kunth*	Arecaceae	Leaves
30	*Phyllanthus emblica L.*	Euphorbiaceae	Fruit
31	*Piper longum L.*	Piperaceae	Fruit, Stem & Root
32	*Piper nigrum L.*	Piperaceae	Fruit & Stem
33	*Pongamia pinnata (L.) Pierre*	Fabaceae	Bark
34	*Pseudarthria viscida (L.) Wight & Arn.*	Fabaceae	Root
35	*Rubia cordifolia L.*	Rubiaceae	Root
36	*Schleichera oleosa (Lour.) Oken*	Sapindaceae	Seed
37	*Sida rhombifolia L.*	Malvaceae	Root
38	*Solanum torvum Sw.*	Solanaceae	Root
39	*Spondias pinnata (L. f.) Kurz*	Anacardiaceae	Bark
40	*Stereospermum colais (Buch.-Ham. ex Dillw.) Mabb.*	Bignoniaceae	Root
41	*Strobilanthes ciliatus Nees*	Acanthaceae	Root
42	*Symplocos cochinchinensis (Lour.) Moore ssp. laurina (Retz.) Nooteb*	Symplocaceae	Bark
43	*Terminalia bellirica (Gaertn.) Roxb.*	Combretaceae	Fruit
44	*Tinospora cordifolia (Willd.) Miers.*	Menispermaceae	Stem
45	*Vateria indica L.*	Dipterocarpaceae	Resin
46	*Wrightia tinctoria (Roxb.) R. Br.*	Apocynaceae	Leaves

1.2. PALGHAT GAP REGION - PALAKKAD DISTRICT, KERALA

The documentation of post flood scenario were conducted in different forest ranges near to Palghat Gap region 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.

The destruction of largest patch of vegetation happened in Akamalavaram section with surface vegetation of average 80 x 40 sq.m area being washed away, uprooting several tall trees like *Xylia xylocarpa, Grewia tiliifolia, Ficus racemosa, Schleicher aoleosa, Holoptelea integrifolia* and some smaller trees like *Chionanthus mala-elengi, Helicter esisora L., Artocarpus hirsutus, Dalbergia latifolia* and *Ixora brachiata* and climbers like *Anamirta cocculus* and *Spatholobus parviflorus*. 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 vanished from the area. 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 *Synedrellan odiflora*. 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.

Ayyappanmala landslide caused heavy destruction resulting 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. 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. Also there is a high chance of forest fire in these dry areas. Landslide created a new channel for the flow of rain water through hill.

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 KaikattiGhat road, Chandramala, Palli, Kootengad, Vannathippalam, Brookland Estate, etc.

MAJOR FINDINGS:

1. The landslides, land subsidence or mudslips happened in inclined planes where the slopes were between 22 – 28.
2. 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.
3. The ground vegetation experienced washing off in heavy downpour along with top soil.
4. Serious damages to vegetation especially trees, by way of uprooting.
5. The post flood habitat modification has resulted in biological invasion in almost all landslide and mudslide areas.
6. The loss of canopy cover promoted the profuse growth of several invasive and weedy taxa that thrives in bright sunlight. The primary colonizers are invaders with high ecological amplitude like Mikania, Lantana, Chromalaena etc.
7. Excess drying up of ground vegetation and Increase in forest fire in February – March 2019.
8. Quarrying in vulnerable areas is one of the major contributing factors for landslides.
9. 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.

10. The loss for Plantain and Rice in the district due to landslides and associated flood.
11. The major forest trees affected are *Grewia tiliifolia, Ficus sp., Cullenia, Homonoia, Macaranga, Mallotus and Bauhinia racemosa.*
12. Habitat loss to significant taxa such as *Exacum tetragonum, Swertia angustifolia, Sonerilanairii, Canscora perfoliata and Colebrookea oppositifolia.*
13. Loss of habitat for endemics such as *Crepidium resupinatum, Arisaema leschenaultia, Alpinia malaccensis, Biophytum intermedium* etc.

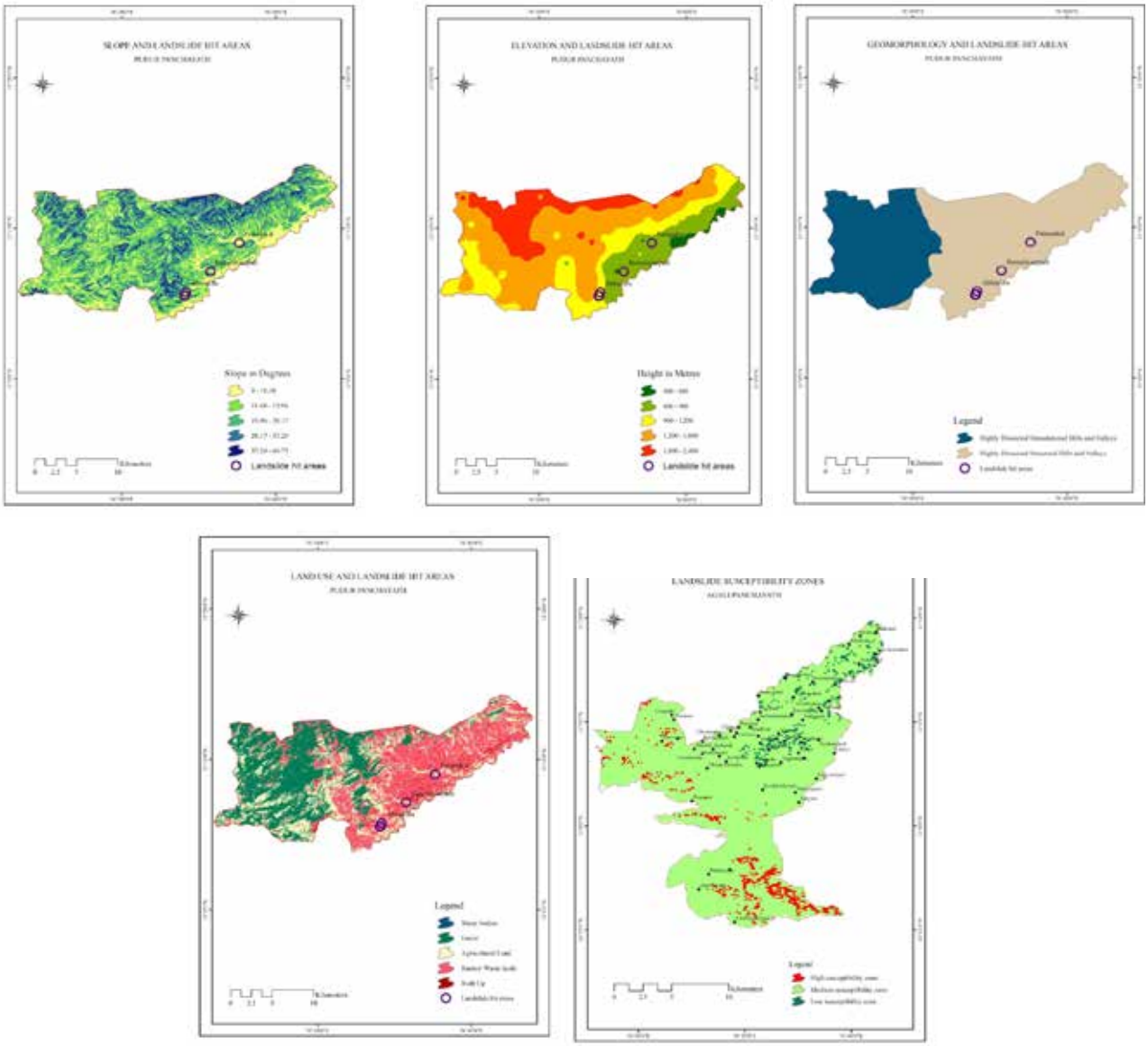

Fig 7. Natural factors triggering Landslide - Pudur panchayat, Palakkad

1.3. ATTAPPADY REGION, PALAKKAD DISTRICT,

Attappady block, situated in the Mannarkkad taluk of Palakkad district lies in between the Nilgiri hill ranges in the North and Vellinkiri hill ranges in the South; both having a height of over 1200 meters. Attappady is one of the oldest and largest tribal settlements with a population of over 30,000. The tribal society in Attappady can be divided into three communities: the Kurumbar, Mudugar and Irular. Attappady, a land of 74590 hectares is itself home to a variety of habitats from evergreen to dry deciduous forests nurtured by

river Bhavani and its tributary Siruvani. To its western and eastern sides lie the Buffer Zone of Silent Valley National Park and Siruvani Muthikulam Hills, where biodiversity studies are done extensively. On the basis of geographical and climatic peculiarities, it is possible to differentiate the region into two zones, viz.; Western Attappady that receives about 3000mm annual rainfall and Eastern Attappady, which is a rain shadow region, receiving less than 1000mm of average annual rainfall. Erratic rainfall with poor soil moisture retentivity has rendered these lands an erosional landscape leading to desertification. Attappady is a landslide prone area and for the present study seven parameters such as slope, elevation, geology, geomorphology, soil type, drainage and land use are taken on causative parameters and zonation map has been prepared. Two panchayaths of Attappady has been affected by flood and landslides. The flood affected and landslide hit areas were mapped using geoinformatics tools. Landslide susceptibility zones were identified.

MAJOR FINDINGS

I. Natural factors triggering landslides

a. Slope details of landslides and flood hit areas of Attappady region

Slope is the most substantial natural factor triggering landslides. Expressed as a percentage or degree, this factor is directly proportional with the possibility of landslide occurrence. Attappady block can be grouped into five categories based on the degree of slope viz, 0-10.67^0 , 10.67^0-18.74^0, 18.74^0-27.11^0, 27.11^0-36.92^{0}and 36.92^0-73.55^0. As the value of slope increases the likelihood of landslide increases, 6.24 percent of total area of Attappady is having a slope of 36.92^0 and above. It is found that the value of slope is more at Pudur Panchayath, located between the latitude of 11^{0}0'0''N and 11^{0}15'0''N and at a longitude of 76^{0}22'12" E to 76^{0}44'23" E. Since this area is having high degree of slope it is more vulnerable to landslides.

b. Elevation details of landslides and flood hit areas of Attappady region

Elevation is another terrain factor that triggers landslides. The higher elevation areas are mainly concentrated towards the North and North-Western parts that constitute 14.48 % of total study area. It is observed that landslide hit areas lies between the elevations of 1200m to1600m. Pudur Panchayath is severely affected by landslides during the 2018 floods and almost all landslide hit areas are located at an elevation of 600m to 900 m.

c. Geology details of landslides and flood hit areas of Attappady region

Lithology of an area determines land stability. Attappady lies in the Attappady-Mettuppalayam shear zone. Presence of strong, stable and hard rocks imparts stability to the slope, making them less susceptible to landslide. The natural strength of rocks can be affected by the presence of joints, fractures, extent of weathering etc. Charkonite and Charnokite gneiss is mainly found in Pudur Panchayathh. Charnockites are easily exposed to weathering and anthropogenic activities and highly susceptible to landslides.

d. Soil details of landslides and flood hit areas of Attappady region

The soils of the area are highly eroded in nature and less productive with textural classes varying from sandy loam to loamy sand in the upper reaches and clay to clay loam in valleys. . Two benchmark soil types identified in Attappady are Agali and Utharampallam. Agali type of soil is found along the valleys and is loamy in texture. Utharampallam group of soils are clayey in nature. Utharampallam soil share 74.52 percent of Pudur panchayath and is more prone to landslides.

e. Land use details of landslides and flood hit areas of Attappady region

Land use is a major factor that influences landslides. Activities like deforestation, unscientific cultivation practices, urbanization, land reclamation etc. influence the incidence of landslides. Areas with sparse vegetation are more prone to landslide in contrast to densely vegetated areas due to more erosion. The land cover types of this area is divided into five types viz, water bodies, forest, agricultural lands, barren/waste land, build-up lands. The effect of weathering and erosion is more in areas of sparse vegetation. Agriculture in steep slope increases the susceptibility of landslide. Plantation agriculture is practised along the slopes in Attappady.

f. Landslide hit areas and susceptibility zones

Landslide hit areas like Edavani, Aralikkonam, and Bhutayar falls in the zone of highly dissected structural hills and valleys with Charnockite basement.From this study it is evident that the North, North-East, and Southern regions of Attappady is block panchayathh are more prone to landslide. It is to be noted that the vast majority of landslide prone areas falls in the Agali panchayath and that to along the left bank of the river Bhavani. It is to be noted that among the crucial variables identified, selective classes such as highly dissected structural hills and valleys with slope between 10° to 30 , having an elevation ranging between 600 to 1200 metres, moderate drainage density, and intensely cultivated agricultural land were marked with a maximum incidence of landslides.

In the study area, a total of six landslide incidences were recorded during the field survey. Slope and land use are the two parametres that triggered landslides in Attappady block. Vast majority of the landslides in the study area occurred in high and very high slopes, ie slopes ranging from 15° - 30° and 30° to 45°.Slopes above the 45° do not recorded any landslide event, since they are mostly barren rock surfaces. The other major parameters that influence the landslides in Attappady are a Relative relief of 600 to 800 metres, the presence of charnokite/charnokite gneiss, highly dissected structural hills and valleys, and Barren/waste land. The landslide that occurred in the forest area is near Aralikonam.

g. Flood affected areas in Attappady

Flood in the study area was mainly confined to the river banks. The places badly affected by flood are Aralikonam, Chinnaparambu, Kallamala, Jellippara, Daivakund, Dhonikund, Kattekkad, Chitoor, Nakkupathi, and Vitiyur. Of these Kallamala and Chinnaparambu is located along the bank of a tributary of Nelli Puzha River.

i. About 251 species of angiosperm have been identified in the area and the majority of angiosperm species are represented by Asteraceae family followed by Fabaceae. 51 trees, 60 shrubs, 110 herbs and 30 climbers were also identified. Edavani and Thudukki areas are comparatively rich in biodiversity.

ii. 12 pteridophyte species and 13 lichens were also reported from the flood hit localities.

iii. The study revealed the presence of 215 identified faunal species under 88 families and 186 genera which included Butterflies, Odonates, Other Insects, Fishes, Amphibians, Reptiles, Birds, and Mammals.

iv. The diversity of larval host plants of butterflies in the study area were documented and a total of 75 species were recorded. A total of 12 endemic species belonging to various ranges were recorded, four in butterflies, four in birds, one amphibian and three fishes.

v. A total of 102 out of the 215 faunal species species recorded were under the Least Concern (LC) category of IUCN. Among the diversity recorded, 6 of the species are protected under Schedule I, 14 under Schedule II, 62 under Schedule IV.

vi. Flood associated erosion and deposition have caused a noteworthy alteration in the soil parameters of the flood-hit areas of Attappady. Statistical analyses have confirmed the significant variation of Organic carbon, Nitrogen, Sodium, Potassium, Magnesium, Calcium, Iron, Cadmium, Clay, Silt and Sand.

vii. Impact of flood on soil: Quantity of clay and silt have decreased and sand has increased post flood. These changes affect the soil aeration and water holding capacity. The study has also revealed a considerable impact on the population of fungi and Actinobacteria in the riparian areas. Immediate actions are to be taken to retain the soil health for the wellbeing of life in all forms.

viii. Fauna : Some larval host plants of butterflies like Crateva magna, Pongamia pinnata, were the major casualties. This may have a declining impact on the number of respective butterfly species. Hesperiids and some Nympalids like Bush-browns were comparatively less than usual. It can be due to the drying up of their hostplant-grasses.

1.4. NELLIYAMPATHY FOREST RANGE, PALAKKAD

Nelliyampathy hills harbours diverse habitats and borders the southern part of Western Ghats to Palakkad Gap spread over an area of 285 km2. The Chundakkadu landslide (year 2000) was the first of its kind that occurred in the Nelliyampathy hills in the recent history. The Nelliyampathy road sides were greatly affected by landslides with fifty-five locations along the road side greatly affected. Maximum destruction was noticed in Brookland region.

MAJOR FINDINGS

- ✓ A total of 165 species has been reported form roadsides of Nelliyampathy. Many Lauraceae family members like *Litsea wightiana, Alseodaphne semicarpifolia* were destroyed. Many woody plants like *Casuarinas equisetifolia, Syzigium aromaticum, Holigarna arnottiana, Schleichera oleosa, Erythrina variegata,Toona ciliata, Macaranga peltata, Szygium cumini* etc. were destroyed.
- ✓ All the flood affected areas studied are abundant with many invasive plants such as *Mikania micrantha, Mikania scandens, Pennisetum polystachion* etc. *Trema orientalis*, an exotic species is abundantly seen in all the areas. *Trema orientalis* is showing secondary succession with the seedlings emerging to the shrubby stage and in course of time it is expected to flourish in these areas.
- ✓ *Musa accuminata* was noticed in which is supposed to be the parent plant of all hybrid varieties of cultivable musa. This plant is not reported earlier in Nelliyampathy.
- ✓ In the current study, many of the endemic and rare species has been reported from the areas hit by the landslides. It includes species like *Arenga wightii, Premna paucinervis, Strobilanthes ciliates and Strobilanthes barbatus, Stereospermum colais, Casuarina equisetifolia, Syzigium aromaticum, Holigarna arnottiana, Schleichera oleosa, Erythrina variegata, Toona ciliata, Macaranga peltata, Szygium cumini etc*. were destroyed. *Stereospermum colais* found in Pooncheri location of Ayiloor commonly called as yellow snake tree was found whose parts are used as medicine for intestinal worms. In seetharkund region, a type specimen which is considered as holotype of *Premna paucinervis*, (Lamiaceae) were found to be destroyed during the landslide. The vulnerable Arecaceae plant, *Arenga wightii* is predominant in many sights of Kundrachola, along Nelliyampathy Roadside (Altitude range of 300-600m), padagiri and Seetharkund whereas *Cleistanthus collinus* was recorded along the Nelliyampathy Roadside (Altitude of 270m) and also at Kayaradi region. The vulnerable tree *Dalbergia latifolia* was recorded in Kaikatty, Ayiloor and also along the Nelliyampathy Roadside in the range 270-380m and *Euonymus angulatus* was recorded from Seetharkund at a height of 900m. The endangered Hopea ponga was recorded at an altitude of 600 m . The vulnerable *Cayratia pedata* was recorded from Ayiloor and Thekkekulambu at an altitude of 80m. All these Vulnerable and endangered plants survived in the landslide hit areas of Nelliyampathy Forest range with damage
- ✓ Compared to other faunal groups, ground active forms are greatly affected by the landslide which is clearly visible from the reduced recordings in the affected areas. Butterflies and Odonates show higher diversity in the landslide hit areas which serves an open area for these winged animals. A total of 81 faunal families were recorded among which the Nymphalidae shows highest diversity. The highest diversity was recorded in the Aluvuseri region with 65 species followed by Vazhakkund region with 62 species.
- ✓ The beetle *Sandracottus sp.* belonging to family Dytiscidae, is a new report from Kundrachola region of Nelliyampathy forest range. This is the second recorded observation of this Coleoptera in Kerala. It is also the first report from Nelliyampathy.

1.5. ATHIRAPALLY PANCHAYAT- THRISSUR

The Athirapilly Grama Panchayath has nearly 70% of the rich forest area with high biodiversity and conservation value with four important forest administrative boundaries i. Vazhachal Forest Division (232.83 Sq Kms and 47.61 %) and ii.Chalakkudy Forest Division (41.754 Sq Kms and 8.5 %) iii. Parambikulam Wildlife Sanctuary (61.463 Sq Kms and 12.57 %) iv. Malayattur Forest Division (4.221 Sq Kms and 0.86 %) coming under Central Forest Circle of the Kerala Forest Department.

A total of 28 landslides were recorded during the study. Among these 11 were small landslides and 4 were medium landslides and 13 were landslides of large dimensions. Average dimensions of the landslides estimated to be 0.005 ha for small landslides, 0.075 ha for medium landslides and 4.25 ha for large landslides.

MAJOR FINDINGS

- ✓ The impact assessment of landslides on riverine habitats showed heavy damages in the Chalakkudy river within the boundary of the Athirapilly Grama Panchayath. Out of the 28 landslides in study area 10 were clustered landslides, with huge impacts.
- ✓ The roads along the hilly terrain with slope ratio 1:3.2 were the actual impact locations of the landslides.
- ✓ Medium and small landslides also well correlated with the presence of at least small roads on steep terrain. Construction of roads cutting across steep forest areas, degraded landscape, without much protection to the embankments found to be the major reason for landslide.
- ✓ The degraded landuse without much vegetation cover also contributed for landslide. 10% of the landslides happened because of the steep cutting streams in which the entire stream structure came down in steep areas. Similar observations were available in many of the landslide areas that happened across Kerala in the hilly terrains such as Silent Valley, Nelliyampathy and Munnar.
- ✓ Hence a total of 283.72 ha of land within Athirapilly Grama Panchayath were completely destroyed due to the landslide during the flood 2018. Of which 12.72 ha of land loss was in residential areas and the remaining was in the good quality natural forests. Since the majority of the landslides were concentrated in the higher slope and medium elevation areas especially along the Anamalai road the major loss happened to the good quality 236.52 Ha of Medium Elevation Evergreen forests. This was followed by 0.0043 Ha of degraded Medium Elevation Evergreen forest, 4.25 Ha of the Semi evergreen forest and 21.259 Ha of the Low elevation evergreen degraded forest.
- ✓ Major reason is the improper construction of roads along high slope or removal of vegetation cover in steep flowing streams. The road construction along the steep terrains requires much physical support for the embankments. The steep cutting or the straight running streams and streams falling from steep terrains with more

than 70 % catchment above with degraded natural vegetation in the hill terrain shall be notified as 'Vulnerable zones' of landslides. A Total of 5 landslides occurred in residential areas one in Non- tribal land Pandarampara and 4 landslides occurred in the tribal agricultural land mainly in Thavalkkuzyppara, Anakayam, Adichilthotty and Kappayam. Special action plans has to be developed for the restoration of the residential as well as agricultural areas in these locations.

- ✓ One of the high impacted landslides occurred at Pandarampara area near Vettikuzhin in the 1st ward of the Athirapilly Grama Panchayath. Quick normal recovery is not possible in this site and require additional support for restoration of the land, vegetation and the streams. The Anakkayam Tribal settlement is another badly affected area due to a clustered huge landslide that happened along the Anamalai Road in the anakkayam Valley. Being a PVTG tribal group with special right under FRA 2006 including the CFR and habitat right Their Grama Sabaha has to be consulted to prepare a proper relocation plan.
- ✓ The forests areas of Athirapilly region comes within one of the high biodiversity rich forests tracts.The present study revealed 1164 species of flowering (angiosperm) plants. These plants belong to a total of 692 genera, 142 families. *Cycas circinalis, Gnetum edule* are commonly seen wild gymnosperms plants apart from few garden varieties. A total 61 Pteridophytes taxa were enumerated from the study area, which include 52 species of true ferns and 10 species of fern allies. Chalakkudy River, Sholayar River and the wetlands are good natural habitat for aquatic, microscopic plants like algae. A total of no of 242 algae were enumerated in the region. Out of the 1164 species of plants listed, 269 of them are endemic 70 comes under IUCN threatened category.
- ✓ Impact on endangered flora : The present estimate on affect of flood on Endemic and Endangered taxa revealed that nearly 63 Endemic plants were affected during the landslide and flood. Of them 24 are endemic to Southern Western Ghats which includes *Cinnamomum riparium, Cinnamomum sulphuratum, Cullenia exarillata. Dipterocarpus indicus, Drypetes venusta, Dryptes malabarica* etc and 27 are endemic to Western Ghats including *Calamus hookerianus, Calamus thwaitesii, Calophyllum calaba, Canscora diffusa, Canscora pauciflora, Capparis rheedei etc, Diospyros candolleana, Ensete superbum, Diospyros paniculata, Ficus virens* etc are endemic to Peninsular India and *Artabotrys zeylanicus* is endemic to Peninsular India and Sri Lanka.
- ✓ A detailed analysis of 13 endangered species reveled that a total of 1200 individuals may be damaged or lost due to landslide. Detailed species composition of these areas were given for prioritizing ecorestoration activities.
- ✓ Awareness shall be created locally on other endangered species such as trees like *Cryptocarya anamalayana, Kingiodendron pinnatum*, riverine herbs such as *Lagenandra nairii, Willisia selagenoides*, reptiles such as Cochin Forest Cane Turtle, amphibians like The balloon Frog etc.

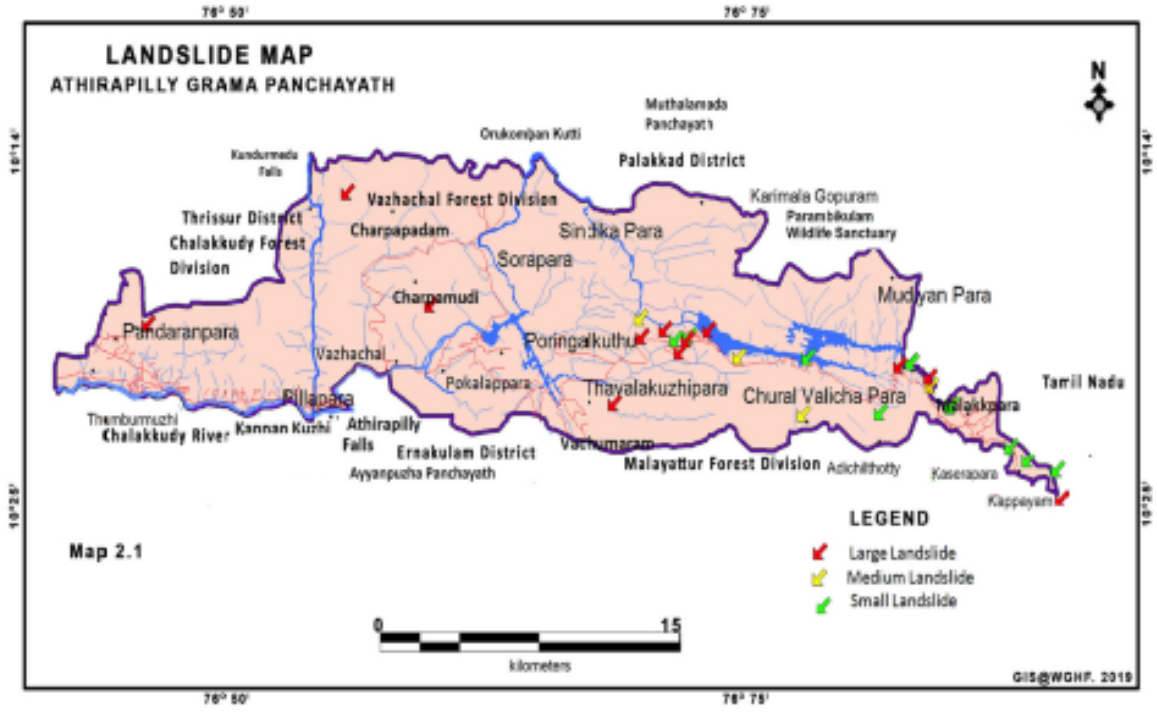

Fig. 8. Landslide Map of Athirapally Grama Panchayats

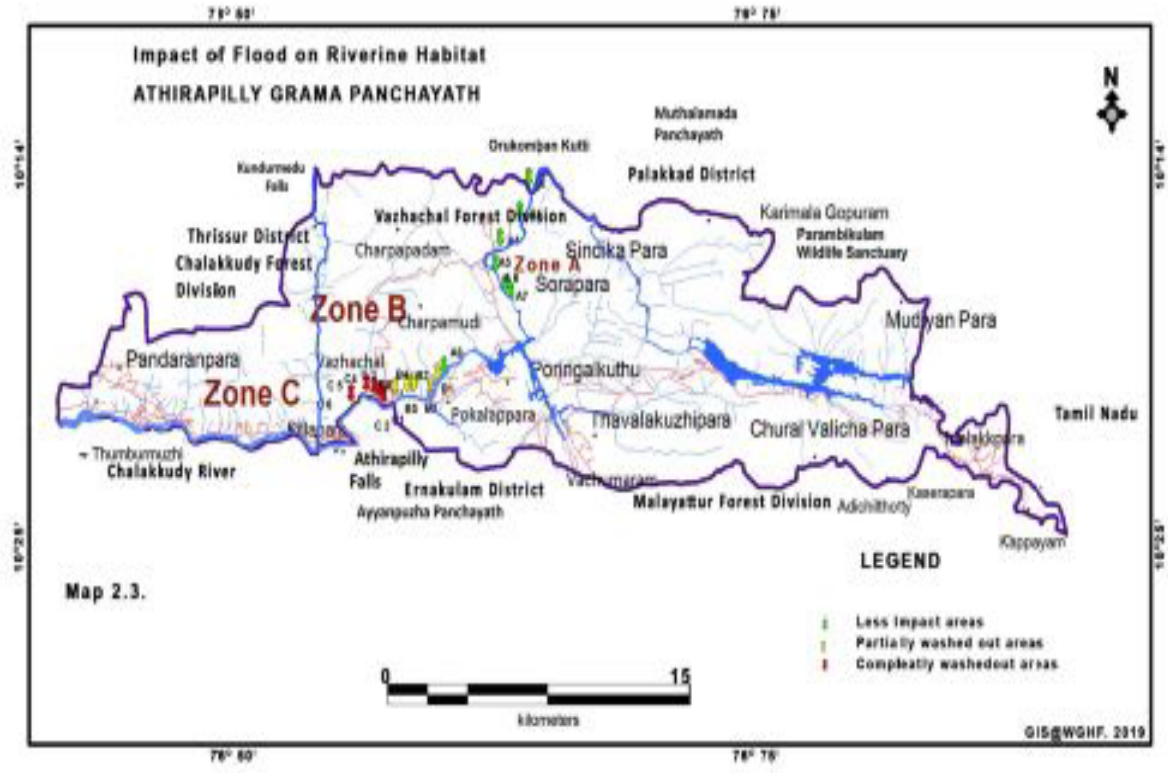

Fig. 9. Map showing impact of flood on riverine habitat- Athirapally Grama Panchayats

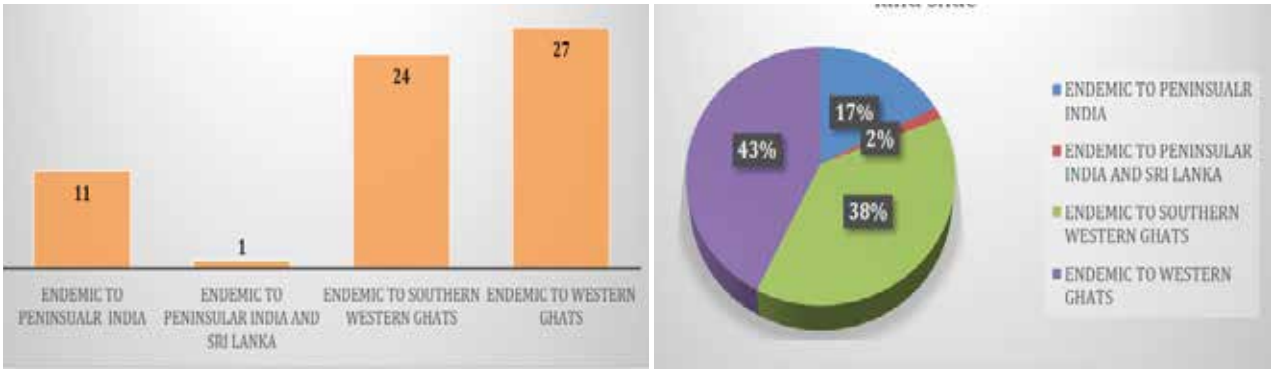

Fig. 10 Endemic and thretend plants affected by flood/landslide

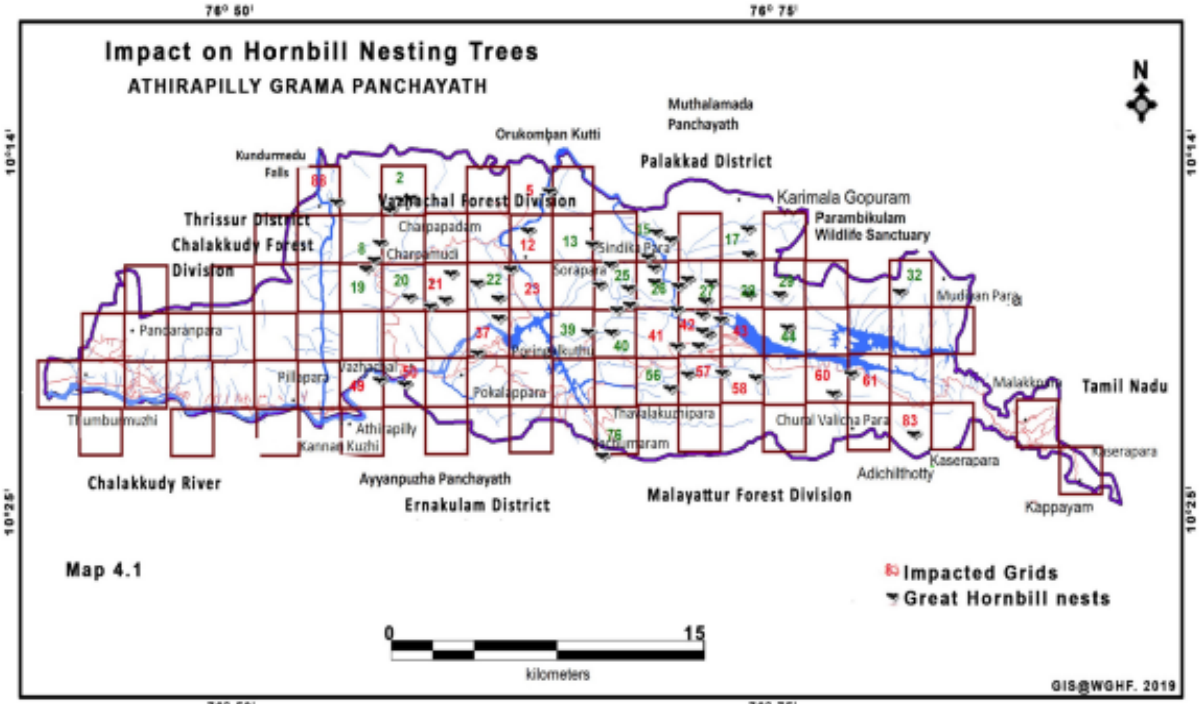

Fig. 11 Map showing impact on Hornbill Nestling Trees - Athirapilly GP

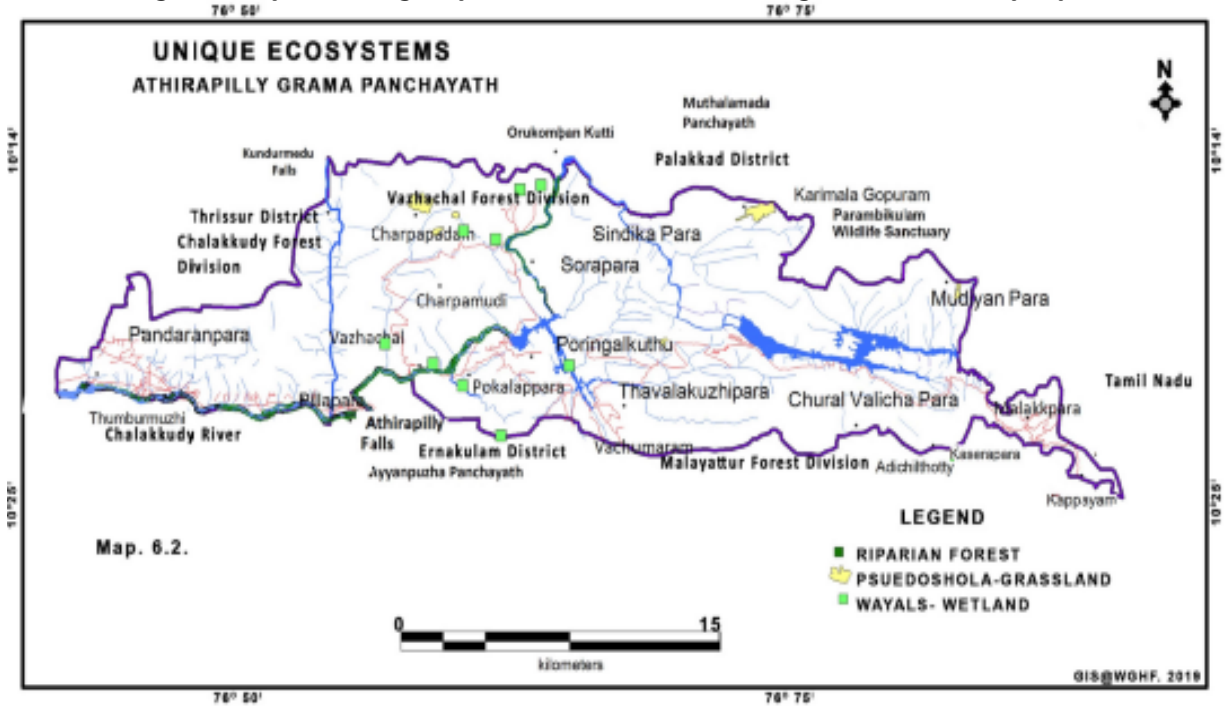

Fig. 12 Map showing Unique Ecosystems - Athirapilly GP

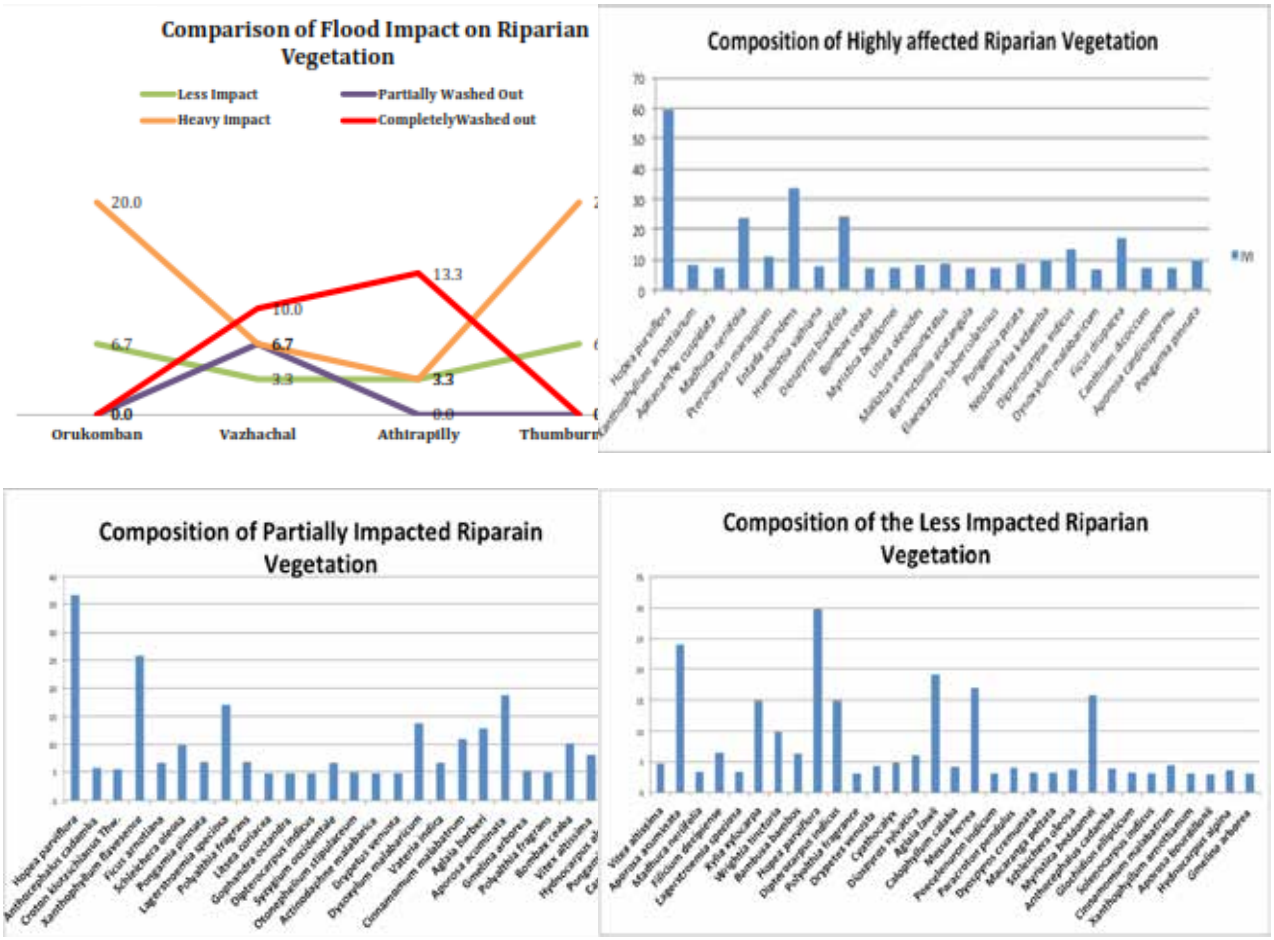

Fig. 13. GRaph showing impact of flood on riparian vegetation

Table 3. Species affected by Flood/Lanslide- Athirapilly GP

No.	Species	Local Name	Family	Type of impact
1	*Actinodaphne malabarica*	Mulagnari	Lauraceae	Land slide
2	*Alstonia scholaris (L.) R.Br.*	Ezhilampala	Apocynaceae	Riparian : Flood impact
3	*Amomum canniparum (Wight) Benth. ex B*	Peethal	Zingiberaceae	Land slide
4	*Amorphophallus sp*		Araceae	Riparian : Flood impact
5	*Aporosa acuminata*	Kallidala	Euphorbiaceae	Land slide
6	*Aporosa cardiosperma (Gaertn.) Mer.*	Vetti	Euphorbiaceae	Riparian : Flood impact
7	*Barringtonia acutangula (L.) Gaertn.*	Neer Pezhu	Lecythidaceae	Riparian : Flood impact
8	*Bombax ceiba L.*	Elavu	Bombacaceae	Riparian : Flood impact
9	*Calamus thwaitesii, Becc.var. canarana, Be*	Aanachooral	Palmaceae	Riparian : Flood impact
10	*Calophyllum calaba L.*	Cherupunna	Calophyllaceae	Riparian : Flood impact
11	*Calophyllum polyanthum L.*	Punnapam	Calophyllaceae	Riparian : Flood impact
12	*Capparis reedii DC., Prodr.*	Kakkamullu	Capparidaceae	Riparian : Flood impact
13	*Carallia brachiata (Lour.) Merr.*	Vankana	Rhizophoraceae	Riparian : Flood impact
14	*Ceiba pentandra (L.) Gaertn.*	Poola	Bombacaceae	Riparian : Flood impact
15	*Cinnamomum malabatrum (Burm. f.) Blum*	Vayana	Lauraceae	Riparian : Flood impact
16	*Cinnamomum riparium Gamble.*	Attukaruka	Lauraceae	Riparian : Flood impact
17	*Clerodendron infortunatum Linn.*		Verbenaceae	Riparian : Flood impact
18	*Colocasia esculenta (L.) Schott*	Katuchembu	Araceae	Riparian : Flood impact

19	*Craetaeva magna (Lour.) DC., Prodr.*	Neer math-ala	Capparidaceae	Riparian : Flood impact
20	*Dillenia pentagyna Roxb.*	Vazhapunna	Dilleniaceae	Riparian : Flood impact
21	*Diospyros buxifolia (Blume) Hiern*	Elichevian	Ebenaceae	Riparian : Flood impact
22	*Diospyros paniculata Dalz.*	Karivella	Ebenaceae	Riparian : Flood impact
23	*Diploclisia glaucescens (Blume)Diels*	Vattoli	Menispermacea	Riparian : Flood impact
24	*Dipterocarpus indicus Bedd.,*	Kalpayin	Dipterocarpace	Riparian : Flood impact
25	*Drypetes malabarica*	Pinepothi	Euphorbiaceae	Land slide
26	*Dysoxylum malabaricum Bedd. ex Hiern*	Vellakil	Meliaceae	Riparian : Flood impact
27	*Elaeocarpus tuberculatus Roxb.*	Puzhathanni,	Delaeocarpacea	Riparian : Flood impact
28	*Entada rheedei Spreng.*		Leguminosae	Riparian : Flood impact
29	*Ficus arnottiana (Miq.) Miq.,*	Kallal	Moraceae	Riparian : Flood impact
30	*Ficus exasperata Vahl, Enum.*	Paraam	Moraceae	Riparian : Flood impact
31	*Ficus nervosa*	Karimarav	Moraceae	Land slide
32	*Ficus racemosa L..*	Atthi	Moraceae	MRiparian : Flood impact
33	*Garcinia gummi-gutta*	Kudapuli	Cluciaceae	Riparian : Flood impact
34	*Garcinia wightii Anders.*	Attukaruka	Clusiaceae	Riparian : Flood impact
35	*Glochidion zeylanicum (Gaertn.) A. Juss.*	Neerola	Phyllanthacea	Riparian : Flood impact

Table 4. Priority sites for conservation- Athirapally

Sl. No	Riparian zone	Riparian vegetation	Status of Riparian vegetation	Range	Section / location	Activity	Area (ha)
1.	Low elevation riparian forest at Vazhachal Poringalkuthu reservoir downstream to Athirapilly	Low-elevation evergreen Riparian	Moderately Good and unique High conservation Value	Vazhachal	Upto Vazhachal bridge RB	Protection Planting degraded areas Sps. List 5	20 ha
				Charpa	Vazhachal bridge to athirapilly	Protection Degraded areas Sps. List 5	70 ha
				Athirappilly	Opp Vazhachal falls to Athirapilly LB	Planting riparian belt 50m wide	70 ha
2.	Banks of Sholayar River from downstream of Upper Sholayar Dam	Wet evergreen degraded	Heavily degraded	Sholayar		Planting Sps. List 3 50 m wide	30 ha
3.	Banks of Lower Sholayar downstream 37 to orukombankutty	Low elevation evergreen Riparian	Moderately disturbed	Vazhachal		Planting and Protection Sps. List 3	30 ha (50m x 8 km) LB
4.	Area from Orukombankutty to Karanthodu	Low elevation evergreen Riparian	Moderately good	Charpa		protection	30 ha RB
5.	Karanthodu to Poringalkuthu res	Low elevation evergreen Riparian		Vazhachal		Protection	30 ha
6.	Area from Athirapilly to Thumburmuzhi LB	Very low elevation riparian area	Heavily disturbed Islands are important	Athirapilly		Planting 50m wide riparian buffer See list	50 ha
7	Kannakuzhi thodu LB	Low elevation riparian	Degraded	Charpa		Planting See list	35 ha

2 IMPACT OF FLOOD ON RIVERINE VEGETATION OF PAMBA, PERIYAR, CHALAKUDY, BHARATAPUZHA, KALLAI, CHALIYAR, ACHENKOVIL, MANIMALA, KORAPUZHA, KUTTIYADI RIVER

Wetlands are one of the most productive ecosystems, among them the riparian ecosystems with more dynamic water environment is more complex and diverse. Biodiversity and productivity of stream system in particular are strongly influenced by the composition and structure of streamside vegetation. It is observed that the flood 2018 lead to the loss of riverine ecosystem with continuous changes in the ecosystem functions, a sudden loss of biological productivity, and reduced capacity to support diverse life forms. It may also lead to irreversible change including soil erosion, depletion of water regime (changes in the surface flow and ground water reservoir) and loss of biodiversity. The flood 2018 created an extensive ecological disturbance by formulating a number of new habitat or changing ecological niches especially due to ecological/edaphic barriers which altered floristic wealth and diversity. The newly established species are 'invasive' or 'weedy' with high relative growth and aggressive capacity. The flood also altered the biodiversity by immediate death, changes in the resource availability and also by physical alteration of habitat.

2.1. ACHANKOVIL RIVER BASIN

Most of the low lying areas in Achankovil River beds experienced severe floods especially Venmony, Panthalam, Cheruthana, Payippad, Chambakkulam and Veeyapuram. The mangroves in the Vemband Lake are the brooding site of numerous indigenous/endemic fishes, crustaceans and several animals. The whole river bed was categorized into three zones based on the elevation viz., Upper zone, Middle zone and Lower zone as :

1. **Zone (Upper zoner: 150 - 1300 msl):** Kallar, Kanyar, Kumbharuvatty, Manalar, Mukkada& Forestnursery.
2. **Zone 2 (Middle Zone: 60-150 msl):** Thumpaman, Konathumoola, Sharngakkaavu, Venmony,Kallimel, Kandiyoor, Sanchayakkadavu&Mesthirikkaana.
3. **Zone 3 (Lower zone 10 – 60 msl):** Paayippad, Cheruthana, Veeyapuram, ValiyaPerumpuzha,VaazhakoottamKadavu &NaalukettumKavala.

MAJOR FINDINGS

- ✓ High rate of rarity and endemism of the riparian vegetation along the River Achankovil and its tributaries.
- ✓ 614 Angiosperms, 20 Pteridophytes and 2 Gymnosperms were enumerated from the study area.

- ✓ 20 Pteridophytes coming under 18 genera of 10 families were enumerated from the study area. 12 Pteridophytes were enumerated from upper zone.14 pteridophytes were enlisted from middle zone and 13 from lower zones too.
- ✓ As revealed from the study, Upper Zone including the Achankovil Forest Division has 319 species coming under 276 genera. Middle Zone holds 345 species of 298 genera. In Lower zone, its number is reduced to 305 species under 276 genera.
- ✓ Fabaceae, with 38 taxa is the largest family followed by Poaceae, Euphorbiaceae and Acanthaceae (30 taxa from each family). Asteraceae occupies third position with 23 representations.Rubiaceae with 21 taxa is coming next largest family. Moraceae and Convoluvalaceae have 17 Euphorbiaceae representation. While Orchidaceae family has 16 elements, Cypreaceae and Scrophulariaceae shares 14 members. These 11 families contributes 236 elements which contributes 38% of the entire flora of the riparian zones.
- ✓ 104 elements in the Achankovil Riparian Zones are endemic to Peninsular India of which 20 taxa are facing various threats.
- ✓ Out of 614 plants identified from the study area, 389 plant taxa are non indigenous including naturalized plants, alien/invasive plants, transformers and weeds. Seven noxious weeds were spotted in the riverine bounds viz., *Chromolaena odorata, Lantana camara, Camonea vitifolia, Sphagneticola trilobata, Mikania scandens, Mimosa diplotricha and Ipomoea carnea Jack.ssp. fistulos*. The research revealed *C. vitifoliais* a destructive weed even in swamps. The lowland Vayals also provide habitat for them. Another noteworthy result observed in the study is that, *M.scandens* is slowly invaded into the mangrove forest also. Aquatic weeds are highly infested in lower zone. Of which Cabomba and Eichornia are denoted as notorious weeds.

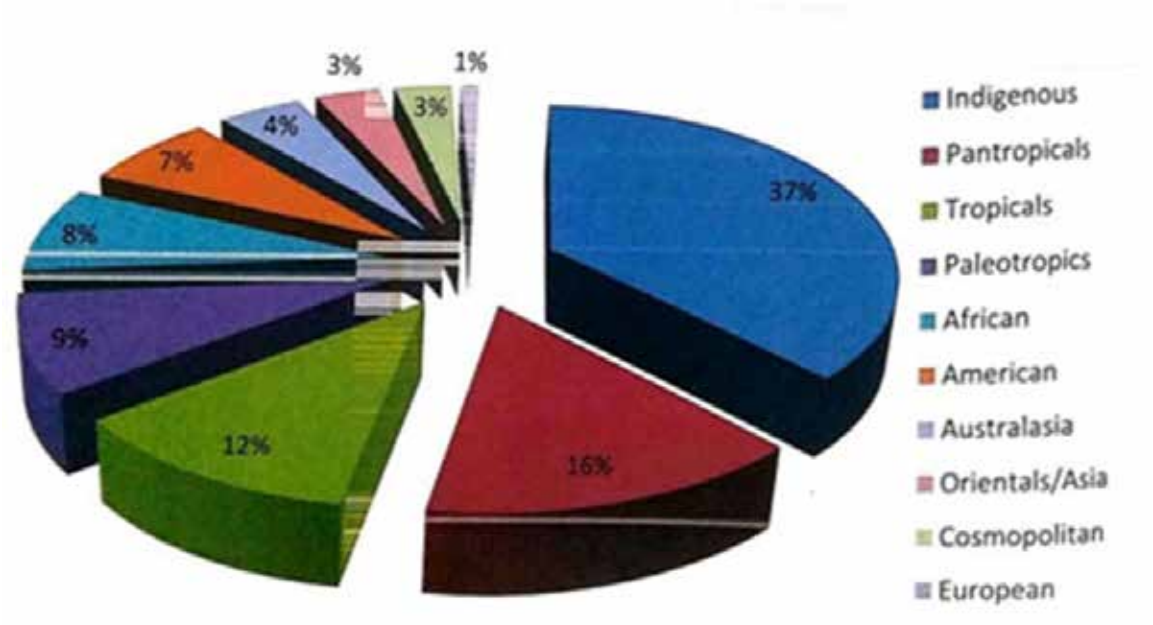

Fig. 14. Phytogeographic affinities of the flora of Achenkovil Riparian zones

2.2. CHALIYAR, KORAPUZHA AND KUTTIYADI RIVER

Kozhikode district of Kerala falls in the watersheds of three main river basins, namely Chaliyar, Korapuzha and Kuttiyadi rivers. The district is drained by 4 of the 41 west flowing rivers of the state. They are the rivers, from the south to north, Chaliyar River, Korapuzha River and Kuttiyadi River, respectively.

CHALIYAR RIVER

Six major streams Chaliyarpuzha, Punnapuzha, Kanjirapuzha, Karimpuzha, Iruvanhipuzha and Cherupuzha constitute the Chaliyar River drainage system. Other important tributes are Kurumanpuzha, Pandipuzha, Maradipuzha, Kuthirapuzha and Karankkodupuzha. During the present study, the river basins of Chaliyar from Beypore (end of Chaliyar) to the Elambaleri hills (origin of Chaliyar) were surveyed.

KORAPPUZHA RIVER

Among the three rivers, Korappuzha is less affected by Flood/ landslides since the river is of just 40 km length flowing through the plains of Kozhikode district and immediately joins with the Arabian Sea at Elathoor. The estuarine areas were well protected from the flood water due to the presence of different mangrove species.

CHALIYAR RIVER

Among the three river basins studied, the Chaliyar river basin shows the most richest floristic diversity since the river mainly flows through dense evergreen and semi-evergreen forest areas of Wayanad and Malappuram districts. In Chaliyar River basin a main landslide occurred in the beginning of Marippuzha, near to the Muthappampuzha. In Chaliyar the severely affected areas are Marippuzha, Elanthukadvu, Thenpara, Mukkorakkal and Vettilappara. Dense forest areas are cleared by the landslides that occurred in Marippuzha-Thenpara areas whereas plantations of Rubber and Areca palms were severely damaged in Vettilappara area.

KUTTIYADI RIVER

In Kuttiadi River basin the major flood/ landslides affected areas are Maruthonkara, Pasukkadavu, Koorachundu, Kakkayam areas. Landslides caused considerable damage to the riparian vegetation especially in Kakkayam forest areas. The combined effect of landslides and flood caused severe damage in the riparian flora of Chaliyar and Kuttiyadi especially in the hilly areas.

MAJOR FINDINGS

- ✓ Analysis of the riparian flora of the flood/ landslide affected areas of Chaliyar, Korapuzha and Kuttiyadi rivers revealed that the flowering plants are represented by 229 species belonging to 167 genera under 74 families. Out of the 229 species Dicotyledons are represented by 157 species and Monocotyledons are represented by 72 species.
- ✓ Population of the riparian species like *Homonoiaretusa, Homonoiariparia, Rotula aquatica, Madhucaneriifolia*, etc. are less affected by the flood. Mangrove species like *Acanthus ilicifolius*L., *Avicennia officinalis* L., *Bruguieragymnorrhiza*(L.) Savi.,

*Excoecariaagallocha*L., *Rhizophora mucronata*Poir., etc acted as a natural barrier against flood in coastal areas. Vulnerable riparian tree like *Ochreinauclea missionis* also survived the flood.

- ✓ *Endemic species:* Out of the 229 species documented from the flood affected areas of Chaliyar, Korappuzha and Kuttiyadi rivers 23 are endemic to the Western Ghats or Peninsular India. The endemic riparian flora is represented by *Cinnamomum malabatrum, Cryptocoryne sivadasanii, Dipterocarpus indicus, Eragrostis riparia, Eriocaulon cuspidatum, Eriocaulon heterolepis, Holigarna arnottiana, Homonoia retusa, Hopea ponga, Indotristicha ramosissima, Lagenandra meeboldii, Lindernia manilaliana, Lindernia oppositifolia, Myristica malabarica, Nymphoides macrospermum, Ochlandra travancorica, Ochreinauclea missionis, Rotala macrandra, Rotala malampuzhensis, Salacia fruticosa, Utricularia lazulina, Vateria indica and Xanthophyllum arnottianum*. Among them, *Vateria indica* is Critically Endangered, *Dipterocarpus indicus* and *Hopea ponga* are Endangered and *Myristica malabarica* and *Ochreinauclea missionis* are Vulnerable as per the IUCN Red List (2019).

  However, populations of endemic and threatened species like *Hopea ponga, Ochalandra travancorica* and *Myristica malabarica* are seriously damaged in the flood affected areas of Chaliyar. The most severely affected groups are shallowly rooted herbaceous plants like *Cyperus* spp., *Eriocaulon* spp., *Fimbristylis* spp., *Hygrophila* spp., *Lagenandra* spp., *Limnophila* spp., *Lindernia* spp., *Rotala* spp., *Utricularia* spp., etc. A good population of *Lagenandra meeboldi* and *Utriculariala zulina*, two rare taxa endemic to the Western Ghats were washed away by the 2018 flood in Kakkayam forest area. Similarly populations of endemic taxa like *Eriocaulon cuspidatum, Lindernia manilaliana, Rotala malampuzhensis*, etc. were also affected in the flood affected areas of Kuttiyadi river basin. The shallowly rooted herbaceous riparian plants were the major victim of 2018 flood. The aquatic/ riparian or wetland loving groups like *Eriocaulon spp., Lagenandra, Limnophila, Lindernia spp., Nymphoides, Rotala spp., Utricularia spp.*, etc. were severely affected by the flood water and many previously known populations disappeared from their locations after the flood.

- ✓ Aquatic ferns like *Acrostichum aureum, Ceratopteris thalicitroides, Marsilea minuta, Osmunda regalis, Pistia stratiotes, Salvinia molesta*, etc are reported from the area. Indigenous aquatic herbs like *Aponogeton natans, Cryptocoryne sivadasanii, Blyxaoctandra, Nymphoides spp.*, etc are washed away by the flood water in many affected areas and are replaced by exotic species like *Cabomba caroliniana, Eichhornia crassipes*, etc.

- ✓ Rapidly spreading invasive alien species are a major threat to the indigenous flora of the flood affected river basins. Disturbances often act as triggers for the proliferation of alien plants. The newly denuded open land created by the flood or landslides provide a good site for emerging rapidly multiplying invasive species like *Ageratum conyzoides, Alternanthera philoxeroides,Eichhornia crassipes,Ipomoea cairica, Mikania micrantha, Mimosa diplotricha, Wedelia trilobata,* etc.

2.3. CHALAKUDY RIVER BASIN

The Chalakkudi River Basin is bounded by the Karuvannur sub-basin on the north and the Periyar sub-basin on the south. The basin consists of about 30,000 ha of wetlands. The basin receives and average rainfall of about 3000 mm. The total drainage area of the Chalakudi river is 1704 sq.km. and out of this 1404 sq.km lies in Kerala and the rest 300 sq.km in Tamil Nadu. The length of the river is about 130 km.

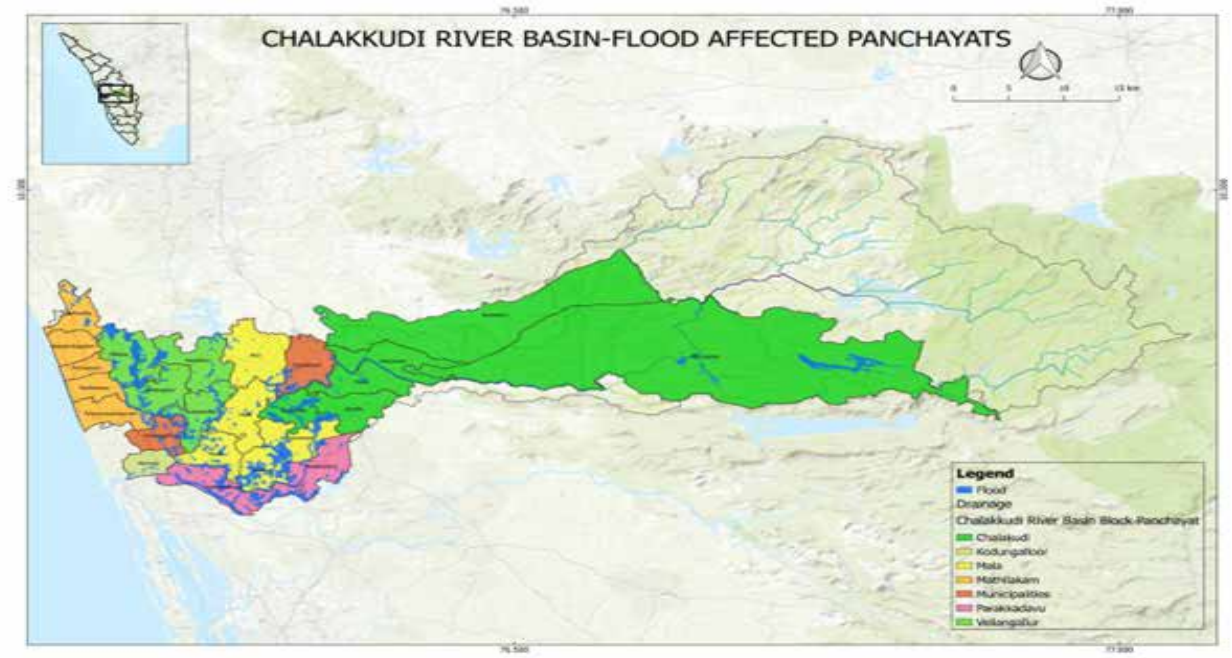

Fig. 15. Map of Flood affected panchayaths- Chalakkudy river basin

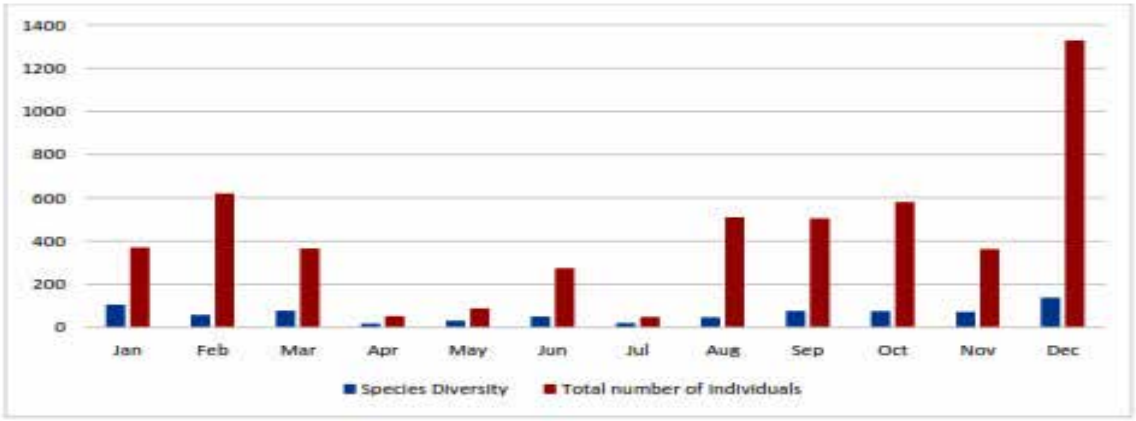

Fig. 16. Graph showing monthly variations in the bird diversity and abundance at Chalakudy River basin during preand post flood.

MAJOR FINDINGS

- ✓ A flood map in the Chalakudy river basin at the Panchayat level was prepared.
- ✓ The Chalakudy block consists of six panchayats of which Kadukutty panchayat was worst affected. In Mala block of five panchayats, Kuzhur panchayat was the worst affected panchayat followed by Annamanada panchayat. Mathilakam block with five panchayats was least affected, while in Vellangallur block with 5 panchayats- Poomangalam panchayat was worst affected, Parakkadav block has 2 panchayats and Chalakudy and Kodungalloor municipality. The fragmentation and loss of natural flood plain has been found to be the major cause for the impact of the flood.
- ✓ The mapping of the riparian forests in the Athirapilly Grama Panchayath reveled there were 283.54 ha of riparian forest distributed from the Orukombankutty upto the Thumboormuzhi area. Among these 43 % (123 ha) were dense low elevation riparian vegetation and the 31% (86.5 ha) were slightly disturbed riparian vegetation

and the remaining 26% (74ha) were riparian islands. The entire areas was divided into 3 zones Zone A : Orukombankutty-Poringal, Zone B Vazhachal rapid, Zone C Vazhachal rapid- Athirapally waterfalls.

- ✓ Data from the total 30 observing points shows that 23 % area were washed out during the flood. 50% of the area had heavy impact 20% were partially impacted and the remaining 6% area only less impacted. This indicates the majority of the riparian vegetation 73% has serious impact.
- ✓ Habitatwise analysis shows out of 8 pools 2 are Least Affected, 3 Moderately Affected and 3 Seriously Affected. Out of 22 riverbanks locations 4 are Least Affected, 7 Moderately Affected, 3 seriously Affected and 8 Completely Destroyed. The riverine habitat with riffles and small pools are critically damaged.
- ✓ 41 species of fishes found in the river lives in this kind of habitat. A decline in fish catch in 2018 as compared to 2017 was observed.
- ✓ The zone B and C, Vazhachal and Athirapilly areas were severely affected as the completely washed out zones are more in these zones. The zone from downstream of the Vazhachal rapids upto the Athirapilly falls had severe impact in which 66.7% of the riparian area especially islands were completely washed out. Some of the large trees in the riverbanks where the river has less slope and maximum width, area downstream to Ittiany area onwards to Athirapilly falls were the exempted zone.
- ✓ The riparian vegetation in the Vazhachal region (Poringal downstream to Vazhachal Waterfalls) was also hit badly with the torrential water flow. The impact is reflected in the destruction of almost 90% of the islands, most of the trees were uprooted except some high Hopea trees.
- ✓ The area from Kannankuzhi upto Thumboormuzhi area also had severe impact, the islands were badly affected with heavy impact (75%). 25% of the area mainly the riparian areas are left with less impact. The maps indicate the left zones have partially disturbed vegetation.
- ✓ In the zone A, area from Orukombankutty upto the Poringalkuthu reservoir 75% of area had severe impact especially the islands. The torrential flow from the Sholayar Dams and the Parambikulam Group dams impacted this zone. The zone from downstream of the Vazhachal rapids upto the Athirapilly falls was severely impacted in 66.7% of the riparian area, and the islands were completely washed out.The low elevation riparian vegetation in the Orukomban – Thumboormuzhi (50-400m) is unique and found nowhere else in the Southern Western Ghats. They were resilient to the flood impact and they functioned well in the areas preventing further damage to the river and riverine biota. The damage that happened to the riparian vegetation were severe in the areas just downstream to the dams especially Poringalkuthu-Vazhachal region and just downstream to the Vazhachal rapids (60-80% damage), just downstream to the Sholayar dam (50-60%).
- ✓ Comparison of the phyto-sociological characters in the different impacted zones indicated difference in species diversity, total number of individuals, density and Basal area. The impact of the flood on riparian vegetation was well correlated with decrease in the phytosociological characters. A comparison with pre flood data showed 66% reduction in Density, total number of individuals and 50% reduction

in the species diversity. At the same time the riparian vegetation actually buffered severe impacts to the riverbanks and surrounding areas.

- ✓ Facultative riparian species such as *Hopea parvilfora, Humboldtia vahliana, Madhuca nerifolia, Homonoia riparia, Syzigium occidentale, Dipterocarpus indicus Barrinctonia acutangula, Mallotus aureopunctatus, Pongamia pinnata, Lophopetalum wightianum, Enteda scandense* etc are highly resistant to the flood. *Ochlandra scriptoria, Cinnamomum ripariaum, Garcinia sps., Lagerstromea sps,* etc also survived to a greater extent but the torrential flow uprooted many of the *Ochlandra scriptoria* patches in the riparian areas. Since most of these species are endemic taxa and have correlation with fresh water fish diversity it is essential to protect and restore the remaining vegetation without altering their community structure and composition.
- ✓ Out of the total 64 Great Hornbill nesting trees in the area 12 nests were affected by flood and 4 nests were lost in the heavy rainfall and flood. The percentage of impact of flood on Hornbill Nesting areas in the study area is 18.75 % and the percentage of loss of Nest trees is 6.2%. Loss of foraging, nesting and roosting sites and trees along the riparian areas and islands from Orukomban to Athirapilly occured.
- ✓ The riparian vegetation is estimated to be nearly 480 ha, distributed in the low-medium elevation area of the Chalakkudy river. It is distributed mainly along the Chalakkudy main river (290 ha, Athirappilly-Vazhachal to Orukombankutty), followed by Karappara river (116 ha, Nelliyampathy-Orukombankutty), Sholayar river 52.2 ha (downstream of Sholayar dam to Orukombankutty), Parambikulam 13 ha (Kuriyarkutty-Orukombankutty) and lest (1.6 ha) along the Kuriyarkutty river at Kuriyarkutty-Thellikkal area.

Riparian vegetation in Orukompan to Elanthikara

- The total length of the main river of Chalakudy is about 144 km out of which the present study has covered 82 km starting from Orukompan to Elanthikara where the river joins Periyar. Continous patches of nautural vegetation on the banks are only in Athirappilly and Ayyampuzha which are predominantly under forests. Continuous barren/built up areas are present in five local bodies viz. Pariyaram, Athirapilly, Meloor, Chalakudy and Parakkadavu.
- Chalakudyar is one of the most highly affected by bank erosion. 84% of the total distance under study and 12 out of the 13 local bodies studied were affected by River bank erosion of various scales. The major local bodies were more areas were eroded in the Chalakudiyar are: Athirappilly, Ayyampuzha, Meloor, Kadukutty, Pariyarm and Chalakudy. The riparian areas of Chalakudy River are comparatively less affected by mud/sand deposition on the banks.
- Chalakudyar is also one of the most highly affected by bank erosion. 87% of the total distance under study and 12 out of the 13 local bodies studied were affected by River bank erosion of various scales. However, most of the erosions are in the medium and low category, only 23% of the eroded areas are under high erosion The present study enlisted 470 species belonging to 108 families from the riparian zone.

- The riparian areas of Chalakudy River are comparatively less affected by mud/sand deposition on the banks. Only about 11% of the total distance under study and 4 out of the 13 local bodies studied were affected by sand/mud deposition. About 16% of the mud/sand deposition is under high category.
- Out of the 13 local bodies studied in Chalakudyar, only 3 require immediate intervention of which only one local body, Athirappilly is having more than 3 km distance of river bank in this category (18 km). Other local bodies in this category are: Chalakudy Municipality (0.9 km), and Ayyampuzha GP (0.8km).

2.4 PAMBAYAR, PERIYAR, AND BHARATHAPUZHA

Four major Rivers of the State, Pampayar, Periyar, Chalakudyar and Bharathappuzha, affected badly during the 2018 August flood/ landslide were selected for the study. For Bharathappuzha three major tributaries, Thoothappuzha (including part of Kunthippuzha), Kalpathippuzha and Gayathrippuzha alone were studied. In order to assess the impact on the ecosystem, the study has mapped the different vegetation types in the riparian area of the four Rivers before flood/landslide using Google Earth maps and a base map prepared.

- The major land use classes identified on riparian areas are mixed tree crops, natural vegetation, barren land, rubber/tea/coffee/oil palm plantations, Teak plantation by forest department, vegetable cultivation and paddy cultivation.
- Mixed tree crops in the riparian areas is highest in Pampa (71%) followed by Bharathapuzha (53%), Chalakudy (52%) , Periyar (44%)
- Natural vegetation is highest in Periyar (30%) followed by Chalakudy (24%), Pampa (11%) and least in Bharathapuzha (4%).
- Rubber plantation is present in all the four rivers – Pampa and Periyar (6%), Chalakudy (2%), and Bharathapuzha (1%). Coconut plantation is present only in 3 rivers – Bharathapuzha (24%), Chalakudy (2%), and Periyar only 1%. Tea and Coffee plantation seen only in Periyar (6% and 1% respectively). Oil Plam plantation and Forest Teak plantation are seen only in Chalakudy (10% and 7% respectively).
- Paddy cultivation in the riparian zone is also seen only in 3 rivers – Pampa (4%) Bharathappuzha (3%), and Periyar (1%). Mixed vegetable crops on riparian zone are noticed in only Periyar and Bharathappuzha (1% and 0.4% respectively).
- The high distribution of barren/built up areas was observed in the riparian areas of Bharathappuzha (16%), Periyar (11%,), Pampa (8%) and least in Chalakudy (3%). These areas have to be given special attention by BMCs while developing action plans of rejuvenation of the river.
- It is found that the banks with barren areas are highly eroded and with natural vegetation is less eroded. The best examples can be found in Vechoochira GP (Pampa); Vathikudy, Kumily and Vandiperiyar GPs (Periyar); Athirapilly, Ayyampuzha and Meloor GPs in Chalakudy and Pirayiri and Puthuppariyaram GPs in Kalpathippuzha.
- The study has noticed that the damages to the riparian species occurred mainly due to high degree of bank erosion and deposition of mud and sand in some areas.
- The study has revealed that 604 species are affected by flood/landslide in various rivers. Complete loss of a particular species is not noticed in the study except

the case of *Lagenandra keralensis* Sivad. & Jaleel. This species is hitherto reported only from its type location at Bhoothathankettu and it was not observed during the present study. The original collection location is now partially filled with sand and the stream where it was present is completely dry now.

- About 60% of the plants the plants affected are herbs, followed by shrubs and trees (15%) and climbers (10%).
- Out of the 604 species partially affected during the flood/landslide event, 359 species (around 60%) are only partially affected or temporarily removed from the place where they are growing during flood/landslide, and sprouted/ regenerated soon after the flood in its original location or in some nearby places. Many of these plants are exotic species (108 numbers). Out of these 76 plants, mostly exotic/ invasive species even spread to more locations.
- In general, the highest number of species affected is in Periyar followed by Pampa, Chalakudy and Bharathappuzha. However, while considering the percentage of species affected and the number of species dried off and uprooted/washed out, the impact is highest in Pampa where 51% of the total species affected, 36 species is dried off and 106 species uprooted/washed out. This is followed by Periyar where 44 % of the total species is affected, 35 species dried off and 86 species uprooted/ washed out. In Chalakudy 42 % of the total species affected, 12 species dried and 78 species uprooted/washed out. Bharathappuzha is the least impacted where 40 % of the total species affected, 21 species dried and 24 species uprooted/washed out.
- The study has analysed species affected with respect to its conservation value and found that 114 out of the 545 species identified as having high conservation value is also lost in some places.
- It is found 11 out of the 40 IUCN red listed species were affected in one or other Rivers. This includes 2 critically endangered species, 4 endangered and 5 vulnerable species. The highest number is in Pampayar with 8 species followed by Periyar (7), Chalakudyar (6) and least in Bharathappuzha with 3 species.
- In the endemic category 47 out of the 197 species were affected. The highest number is in Chalakudy River with 29 species followed by Periyar (25), and Pampa (23) and least in Bharathappuzha with 12 species.
- 70 out of the 334 medicinal plant species identified were affected by the flood/ landslide. Highest impact is in Pampayar with 55 species followed by Chalakudy (41 species), Periyar (34 species) and Bharathappuzha with 33 species.
- It is also noted that 42 out of the 214 species identified by the study was affected in one or other Rivers. The highly affected are in Pampa (32 species), followed by Chalakudy (31 species), Periyar (27 species) and Bharathappuzha (13 species)
- The riparian areas for second stage intervention are highest in Periyar (223 km) followed by Bharathappuzha (87 km), Pampa (72 km) and Chalakudy (47 km) and areas for long term intervention are highest in Periyar (132 km) followed by Pampa (114 km), Chalakudy(77 km) and Bharathappuzha (35 km). Areas which does not need much interventions is highest in Bharathappuzha (122 km) followed by Pampa (35km), Chalakudy (20km) and Periyar (10 km).

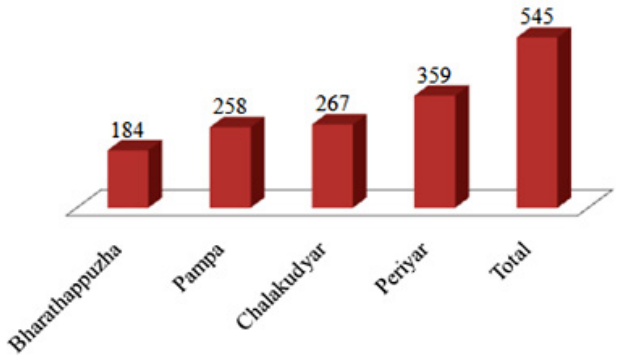

Fig. 17 Distribution of Indigenous Species with High Conservation Value

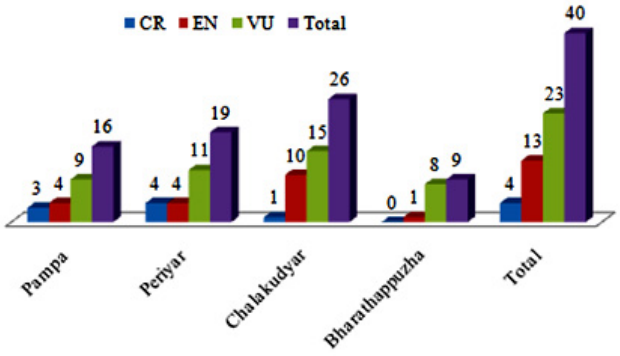

Fig. 18 Distribution Pattern of IUCN Red listed species in the Four Rivers

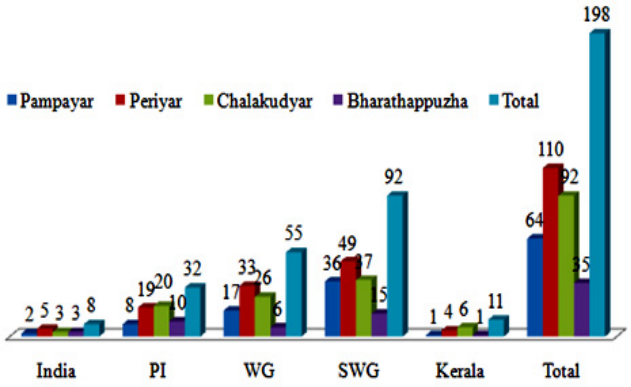

Fig. 19 Distribution Pattern of Endemic species in the Four Rivers

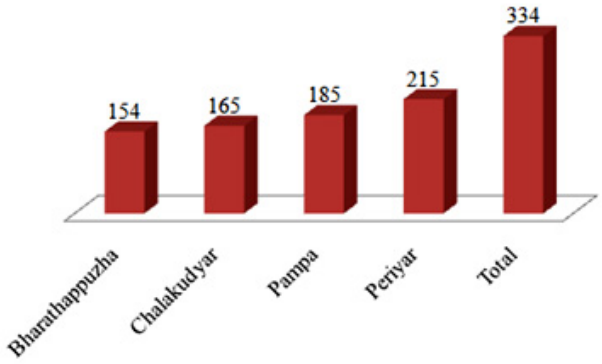

Fig. 20 Distribution Pattern of Medicinal Plants in the Four Rivers

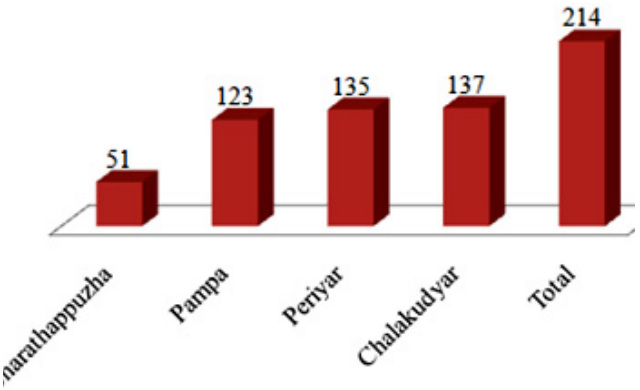

Fig. 21 Distribution Pattern of Plants having other Local Importance in the Four Rivers

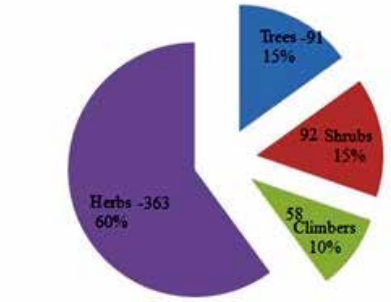

Fig. 22 Species Composition of Plants affected by flood/landslide in four Rivers

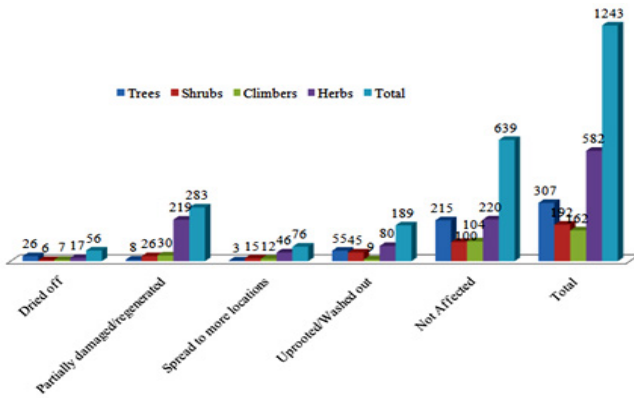

Fig. 23 Number of species affected/not affected by flood/landslide in four Rivers

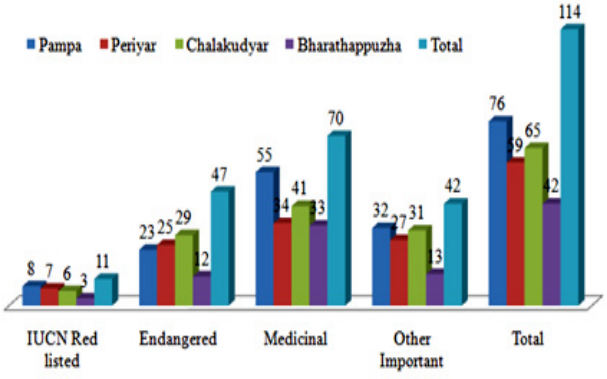

Fig. 24 River wise species of High Conservation value affected by flood/landslide

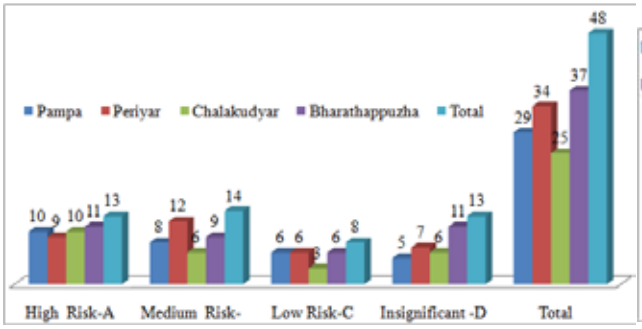

Fig. 25 River wise distribution of invasive species in four Rivers

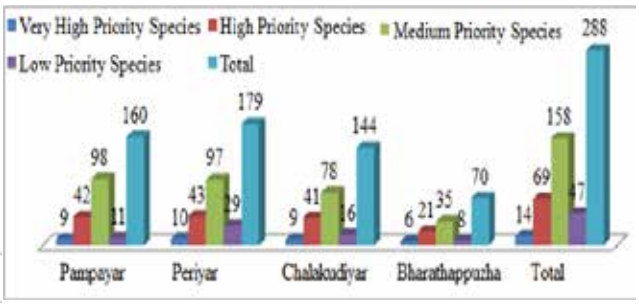

Fig. 26 Prioritised List of species for River Bank Afforestation in four Rivers

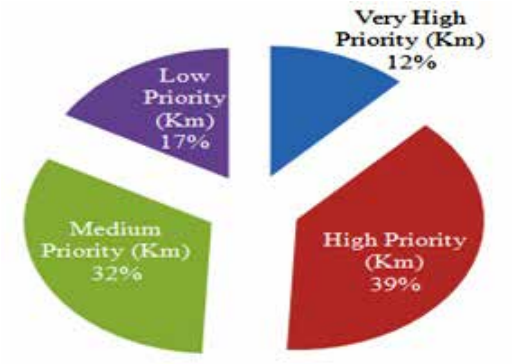

Fig. 27 Riparian area prioritised for intervention in Four Rivers

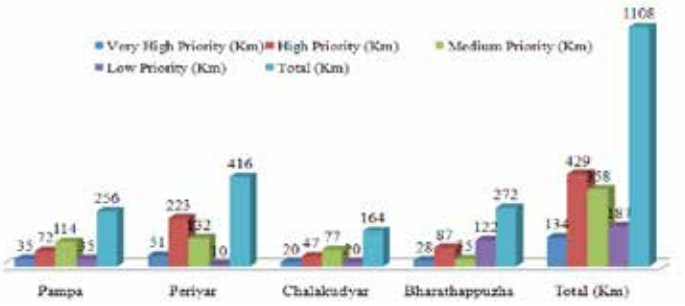

Fig. 28 Total distance of riparian area prioritized for Riparian afforestation programme

Prioritization of areas for intervention

- Based on detailed consultations with various experts, the study has developed criteria for prioritizing the flood/landslide affected riparian areas for intervention by local bodies/BMCs at various stages.The major factors considered are: i) Physical impact of the flood/landslide to the riparian areas, ii) Distribution of species with conservation importance (IUCN Red listed and Endemism), Loss of species with conservation importance (IUCN Red listed and Endemism) in flood/landslide and iv) Distribution and spread of invasive species and vi) Riparian lands use classes
- All together in the four Rivers 12% of area is in very high priority and needs immediate intervention. There are 39% for second stage intervention, 32% for long term intervention and the remaining 17 % requires not much intervention other than monitoring
- Out of the 1108 Km stretch of the four rivers explored during the study, a total distance of 134 Km is identified as very high priority which needs intervention in the first stage. A total distance of 429 Km is identified as high priority for second stage of intervention, a total distance of 358 Km is identified as medium for long term intervention and a total distance of 187 Km is identified as in low priority areas which need not much intervention.
- It is found that the areas for immediate intervention are highest in Periyar (51 km) followed by Pampa (35 km), Bharathappuzha (28 km) and Chalakudy (20 km). However, percentage wise the area requiring immediate intervention is highest in Pampa (14%) followed by Periyar and Chalakudy (12%) and the lowest is in Bharathapuzha (10%).

Table 5. Criteria for Prioritization of plants for Riparian Afforestation Programs

Criteria/Parameters	Score
IUCN Red Listed Species (Maximum Value 20)	
Critically Endangered (CR) /Type location	20
Endangered (EN)	15
Vulnerable (VL)	10
Endemic Plants (Maximum Value 15)	
Kerala (KL)	15
Southern Western Ghats (SWG)	12
Western Ghats (WG)	10
India/Peninsular India (PI)	8
Medicinal Plants	**10**
Other locally Important plants	**10**
Plants mostly growing very close to or inside the River	**10**
Maximum Score	**65**

Table 6. Prioritization Criteria of and scores for Prioritization of Areas for Intervention

Criteria/Parameters	Score
Physical impact of flood/landslide (Maximum Value 20)	
High Erosion	10
Medium Erosion	5
Low Erosion	3
High Deposition	10
Medium Deposition	5
Low Deposition	3
Distribution of IUCN Threatened/Endemic Species (Maximum Value 20)	
Critically Endangered (CR) /Type location	10
Endangered (EN)	5
Vulnerable (VL)	3
Species endemic to Kerala (KL)	10
Species endemic to Southern Western Ghats (SWG)	8
Species endemic to Western Ghats (WG)	6
Species endemic to Peninsular India (PI)/India	4
Loss of plants IUCN Threatened/Endemic Species (Maximum Value 20)	
Critically Endangered (CR) /Type location	10
Endangered (EN)	5

PAMBA

In Pamba about 58% of area are under forest (including grass lands and forest plantations). The percentage of endemism of flora of Pampa river basin is 20.80, which contributes 3.73% of the total endemism of Western Ghats-Sri Lankan biodiversity Hotspot. Large scale agricultural plantations (mostly rubber) are concentrated in highland area. Out of

the total length of the River (176 km), the present study covered the riparian regions for the total length of 128 km from the Pampa Triveni area in Seethathode Grama Panchayat to Mangalassery Boat Jetty where it joins the Vembanad Lake in Punnapra North Grama Panchayat (Plate 5).

MAJOR FINDINGS

- ✓ Exponential increase in the built up area (314%), quick transition of fertile land to waste land (85%) reduction in agriculture land (3%) and marginal decrease in the forest cover (4.5%).
- ✓ Continuous patches of barren built up riparian areas are present in 30 out of the 34 local bodies. The highest area is in the Seethathode GP followed by Pandanad, Nedumudi, Kadapra, Chengannur Municipality and Ranni GP.
- ✓ Nautural vegetation is restricted to four local bodies in the highland area and the highest is in the Chittar GP followed by Kumily, Seethathode and Naranamoozhi. The high distribution of barren areas needs special attention by BMCs while developing action plans of rejuvenation of the river.
- ✓ Pampayar is the second most highly affected by erosion. 13% of the total distance under study and 16 out of the 34 local bodies studied were affected by River bank erosion at various scales. High scale erosions (bank eroded top to bottom) happened mainly in Vechoochira, Chittar, Erumely and Ranni-Pazhavangadi Grama Panchayats.
- ✓ Pampayar is the most highly affected by mud/sand deposition on the banks. 74% of the total distance under study and 27 out of the 34 local bodies studied were affected by sand/mud deposition at various scales. There are 13 local bodies in this category of which most highly affected GPs are: Chittar, Vadaserikkara, Seethathode , Kumily, Cherukole and Vechoochira,
- ✓ The total number of plants recorded is from Pampa River of 549 belonging to 112 families. This includes (392 Dicotyledons, 156 Monocotyledons and 1Gymnosperms).
- ✓ Twenty one tree species are seen in the immediate banks of the River, growing very close to the water flowing areas. They are: *Barringtonia acutangula, Barringtonia racemosa, Bruguiera cylindrical, Calophyllum calaba, Crateva magna, Ficus hispida, Garcinia Morella, Hopea parviflora, Hopea ponga, Humboldtia vahliana, Lagerstroemia microcarpa, Madhuca neriifolia, Mallotus atrovirens, Morinda citrifolia, Neolamarckia cadamba, Ochreinauclea missionis, Syzygium occidentalis, Syzygium salicifolium, Terminalia elliptica, Thespesia populnea and Vitex leucoxylon.*
- ✓ Out of the 34 local bodies studied in Pampayar, 19 require immediate intervention of which the five bodies are having more than 3 km distance of river bank in this category. They are: Chittar (7.6 km), Vechoochira (5.5 km), Cherukole (5 km), Ranni-Pazhavangadi (3.7 km) and Seethathode (3.1 km). Out of the 44 local bodies studied in Pampayar, 16 are there which require immediate intervention of which the 5 local bodies are having more than 3 km distance of river bank in this category. They are: Adimali (14.5 km), Vathikudy (8.9 km), Malayattur-Neeleswaram (3.9 km), Elappara (3.6 km) and Sreemoolanagaram (3.1 km).

PERIYAR

In Periyar major parts of the catchment area are hilly, undulating with a good number of waterfalls and valleys. Some of the hill tops are covered with stunted growth of forests, while others are barren with exposed reeds or with little soil on which grass species exists and ravines with fairly rich soils where moist deciduous forests can be seen. The major forest classes are wet-evergreen, semi-evergreen, moist deciduous, dry-deciduous and pure reed areas and settlements are in the lower reaches, especially in the Aluva, Ernakulam belt. Out of the 244 Km total length of the main River, the riparian areas of 160 Km of the River from Vandiperiyar Bridge (Vandiperiyar GP) to Munampam/Azheekode beach (Pallipuram / Eriyad GP) was explored during the present study.

MAJOR FINDINGS

- ✓ The major environmental issues identified during the preliminary appraisal are mainly related to: i) Pollution and degradation of water body, ii) Clogging of water bodies iii) Sand mining, iv) Clay mining, v) Quarrying, vi) Land use change, vii) River bank encroachment, viii) Tail water diversion, ix) Unresponsive tourism activities and x) depletion of biodiversity.
- ✓ Approximate length of the bank occupied by the encroachers is estimated to be 140 kms on both sides.
- ✓ Mixed tree crops in the riparian areas of the Periyar comes to about 44% of the area under study and are present in 36 local bodies. Puthenvelikkara, Vathikudy, Karumaloor, Udumbannur, Okkal, Kavalangad, Ayyappankovil, Kanjoor, Chengamanadu and Upputhara are the top ten GPs having high areas under this category. The second largest landuse class in Periyar riparian region is natural vegetation (30%). Continous patches of natural vegetation on the banks are only in 13 local bodies under study, restricted to four local bodies in the highland area and the highest is in the Chittar GP followed by Kumily, Seethathode and Naranamoozhi. The major ones are: Kuttampuzha, Adimali, Udumbannur, Vengoor, Ayyampuzha, Kavalangad, Keerampara and Vazhathope. Barren/built up riparian areas present in 11% of the total length and are present in 25 out of the 44 local bodies explored. The highest area is in the Aluva Municipality followed by Keezhumad, Eloor, Kadungallur, Kuttampuzha and Malayttur-Neeleswaram GP. The high distribution of barren areas (12%) needs special attention by BMCs while developing action plans of rejuanation of the river.
- ✓ Periyar is the most highly affected River in Kerala by erosion. 15% of the total distance under study and19 out of the 44 local bodies studied was affected by River bank erosion of various scales. The major local bodies where more areas were eroded in the Periyar are: Vathikudy, Udumbannur, Kumily, Vazhathoppu, Adimali, Ayyappankovil, Vandiperiyar, Kuttampuzha, Kavalangad and Vellathooval.
- ✓ The riparian areas of Periyar are also highly affected by mud/sand deposition on the banks.
- ✓ There are 22 local bodies in the most highly affected category of which the major ones are: Vengoor, Kuttampuzha, Adimali, Udumbannur, Ayyappankovil and Upputhara.
- ✓ Periyar is having the highest number of plant species recorded in its riparian area. The present study enlisted 799 species belonging to 117 families from Periyar riparian zone.

- ✓ Out of the 307 tree species identified 28 are seen mostly in immediate banks of the River. They are: *Aporosa bourdillonii, Barringtonia acutangula, Barringtonia racemosa, Bruguiera cylindrical, Bruguiera gymnorrhiza, Calophyllum calaba, Cinnamomum riparium, Crateva magna, Ficus hispida, Garcinia Morella, Hopea parviflora, Hopea ponga, Humboldtia vahliana, Lagerstroemia microcarpa, Lophopetalum wightianum, Madhuca neriifolia,Mallotus atrovirens, Morinda citrifolia,Neolamarckia cadamba, Neonauclea purpurea,Ochreinauclea missionis, Syzygium laetum, Syzygium occidentalis, Terminalia elliptica,Thespesia populnea, Trewia nudiflora, Vitex leucoxylon and Willisia selaginoides.*
- ✓ Out of the 114 shrubs identified 10 are also seen close to the running water. They are: *Ficus heterophylla, Homonoia riparia, Kandelia candel, Pandanus canaranus, Pandanus odorife,Phyllanthus lawii, Rhizophora mucronata, Syzygium caryophyllatum, Ochlandra scriptoria and Ochlandra travancorica.*

BHARATAPUZHA

About 31% depletion in the natural vegetation cover and 8.7% depletion in wetland agriculture area were seen in the basin. On the other hand the urban spread in the basin increased by 32%.

- Continous patches of nautural vegetation on the banks are restricted to five local bodies of the thoothappuzha tributary only. They are: Karimpuzha, Mannarkkad, Kumaramputhur, Kulukkallur and Aliparampa.
- Continuous barren/built up areas are present in 24 out of the 35 local bodies. More barren areas are found in the Puthussery, Marutha roaad and Parali GPs and Palakkad Municipality of Kalpathipuzha tributary.
- Bharathapuzha is comparatively the least affected River by bank erosion. The major local bodies were more areas were eroded in the Bharathapuzha are: Mannarkkad (Thootha), Pazhayannoor (Gayathri), Thiruvegappura and Cherplassery (Thootha), Puthukkad (Gayathri), Aaliparambu (Thootha), Thiruvillamala and Kavassery (Gayathri) GPs.
- The riparian areas of Bharathapuzha is also comparatively less affected by mud/ sand deposition on the banks. About 26 % of the total distance under study and 23 out of the 35 local bodies studied were affected by sand/mud deposition at various scales. However, only 5% of the total mud/sand deposition is under high category. Majority of the depositions are in Thootha and Kalpathi tributaries.
- The present study enlisted 421 species belonging to 93 families from the riparian areas of the three tributaries of Bharathapuzha. The highest diversity is in the Thootha tributary with 337 species, followed by Kalpathi (253 species) and the lowest in Gayathrippuzha with 210 species.
- Out of the 35 local bodies studied in Bharathapuzha, 14 (12 in Thootha and 2 in Kalpathi) require immediate intervention of which 3 (All in Thootha) are having more than 3 km distance of river bank in this category. They are: Mannarkkad (5.8 km), Cherpulassery (4.2) and Kumaraputhur (3.6 km).
- In Bharatapuzha 10% of its area studied is in very high priority for immediate intervention, 32 % for second stage intervention, 20 % for long term intervention. In the Bharathappuzha very high priority priority areas are highest in Thootha tributary (15.7%), followed by Kalpathi (5.3%) and no such areas identified in Gayathri tributary.

In the case of high priority areas, the highest is in Kalpathi (61.2%) followed by Gayathri (27.3%) and Thootha (24.4%). The areas which needs long term intervention (medium priority) is highest in Gayathri (39%) followed by Thootha tributary (16.2%), and Kalpathi (7.5%). Areas which does not need much intervention (low priority) is highest in Thootha (44%) followed by Gayathri (33.7%) and Kalpathi (26.1%).

Floral Diversity of Riparian Areas

- A total number of 1243 species of phanerogams belonging to 150 families are identified from the four rivers under study. The highest number of species is recorded from Periyar (799) followed by Pampa (549), Chalakudy (470) and 3 tributaries of Bharathappuzha together have 421 species.
- The largest family is Poaceae with 114 species followed by Fabaceae (113), Cyperaceae (64), Rubiaceae (64), Euphorbiaceae (63) and Asteraceae (56).
- Majority of the riparian flora recorded from these four Rivers are herbs (47%), followed by trees (25%), shrubs (15%) and climbers (13%). Out of the 582 herbs identified, 302 are annuals and remaining 280 are perennials. 117 perennial herbs are aquatic or semi aquatic with distribution restricted to the running/stagnant water or water logged/wet areas like marshes, paddy fields etc. There are 15, epiphytes, one parasite perennials and 2 saprophytic annuals.
- Out of the 307 tree species identified 29 are true riparian species growing close to the water flowing areas. They are: *Aporosa bourdillonii, Barringtonia acutangula, Barringtonia racemosa, Bruguiera cylindrical, Bruguiera gymnorrhiza, Calophyllum calaba, Cinnamomum riparium, Crateva magna, Ficus hispida, Garcinia Morella, Hopea parviflora,Hopea ponga, Humboldtia vahliana, Lagerstroemia microcarpa, Lophopetalum wightianum,Madhuca neriifolia, Mallotus atrovirens, Morinda citrifolia,Neolamarckia cadamba,Neonauclea purpurea, Ochreinauclea missionis, Syzygium laetum, Syzygium occidentalis,Syzygium salicifolium, Terminalia elliptica, Thespesia populnea, Trewia nudiflora, Vitexleucoxylon and Willisia selaginoides.* This includes 3 Mangroves.
- 13 out of the 196 shrubs identified are restricted to the immediate boundary of the river. They are: *Ficus heterophylla, Homonoia riparia, Kandelia candel, Pandanus furcatus, Pandanuscanaranus, Pandanus kaida, Pandanus odorife, Pandanus palakkadensis, Phyllanthus lawii,Rhizophora mucronata, Syzygium caryophyllatum, Ochlandra scriptoria and Ochlandratravancorica.* This includes 4 Mangroves.
- Five woody climbing plants viz., *Combretum albidum,Derris trifoliate, Entada rheedei, Ichnocarpus frutescens and Strychnos colubrine* are true riparian growing close to the Rivers.
- Out of the 1243 plants recorded, 116 are seen in the riparian areas of all the four rivers, 180 seen in three rivers, 287 in two rivers and the rest 660 in one river only. Out of the 660 species seen in only one river area, 116 species are recorded only from Pampa, 313 species are recorded from Periyar region only, 115 species are recorded from Chalakudy only and 116 species are restricted to Bharathappuzha region.
- 161 (117 herbs, 29 trees, 13 shrubs and 5 climbers) species are identified true riparian species (aquatic or semi aquatic with distribution restricted to the running/stagnant water or water logged/wet areas like marshes, paddy fields etc.). This include 7 Mangrove species.

- The flora also consists of 197 exotic species of which 48 species are included in the 82 invasive species of Kerala.
- Out of the 1243 species recorded from the study area, 90 species (20 herbs, 14 shrubs, 50 trees and 6 climbers) are cultivated species grown by the farmers along the banks of the river. 60 species out of the 91 cultivated plants are exotic species and it also include 4 invasive species listed by Sankaran et.al. (2013).

Species with High Conservation Value

- The plant other than the cultivated species having high conservation importance are identified based on the parameters like IUCN threatened status (Critically Endangered, Endangered and Vulnerable categories are taken), Endemism (Endemic various regions of India viz. Peninsular India, Western Ghats, Southern Western Ghats, Kerala etc.), Medicinal use of plants in various systems of medicine, other uses like utility for local livelihood, capacity protect river banks etc.
- The study listed 545 species with important conservation values. This includes 198 herbs (33 close to or inside river), 90 climbers (2 close to river), 109 shrubs (9 close to river), and 231 trees (17 close to river).
- It is found that the Periyar is having the highest number of indigenous species with high conservation value with 359 out of the 545 species, followed by Chalakudyar (267), Pampayar (258) and least Bharathapuzha with 184 species.
- 40 species recorded from the study area are there in the Red List Version 2019. Of these 4 are critically endangered (CR) viz. *Dipterocarpus bourdillonii, Ixora johnsonii, Syzygium travancoricum and Vateria indica;* 13 endangered and 23 in vulnerable category
- All the 4 critically endangered species are seen in Periyar riparian area. None of the species were found in the areas studied in Bharathapuzha.
- The highest number of endangered species is seen in Chalakudy River and is having 10 out of 13 species recorded. Pampa and Periyar is having 4 species each and Bharathapuzha is having only one species.
- The highest number of vulnerable species is also seen in Chalakudy River (15 species), followed by Periyar (11), Pampa (9) and Bharathapuzha (8).
- *Vateria indica* is found in three rivers (Pampa, Periyar and Chalakudy). *Dipterocarpus bourdillonii* and *Ixora johnsonii* are fond both in Pampa and Periyar and *Syzygium travancoricum* seen in Periyar alone.
- There are 198 endemic species in the riparian flora of four rivers. Of these 11 are endemic to Kerala, 92 to Southern Western Ghats (SWG), 55 Western Ghats (WG), 32 Peninsular India (PI) and the rest 8 species India endemic.The highest number of endemic species is found in Periyar riparian area (110 species-4 Kerala, 49 Southern Western Gats, 33 Western Gats, 19 Peninsular India and 5 India) followed by Chalakudy with 92 species (6 Kerala, 37 Southern Western Gats, 26 Western Gats, 20 Peninsular India and 3 India). Pampa is having 64 endemic species (1 Kerala, 36 Southern Western Gats, 17 Western Ghats, 8 Peninsular India and 2 India). Bharathapuzha region is having the least number of endemic species with 35 plants (1 Kerala, 15 Southern Western Gats, 6 Western Gats, 10 Peninsular India

and 3 India). 13 species under the endemic category (6 Southern Western Ghats, 2 Western Gats, 4 Peninsular India and 1 India) are found in all the four rivers, 17 species in 3 rivers (7 Southern Western Gats, 7 Western Gats, 2 Peninsular India and 1 India), 31 species in two rivers (1 Kerala, 14 Southern Western Gats, 7 Western Gats and 9 Peninsular India and 1 India) and the remaining 136 species in any one of the rivers (19 in Pampa only, 61 in Periyar only, 44 in Chalakudy only and 12 in Bharathapuzha only)

- Out of the 545 plants identified as having high conservation value, 334 are found medicinally used in various traditional systems like Ayurveda, Siddha, Unani, Homeopathy, Folk, Tibetan, Sowa Rigpa, Chinese etc. and also in Modern medicine and Veterinary medicine. The medicinal plants diversity is high Periyar (215species), followed by Pampa (185 species), Chalakudy (165 species) and lowest in Bharathapuzha (154 species). 7 medicinal plants are IUCN threatened species (1 CR, 3 EN and 3 VU categories) and 32 are endemic (13 Southern Western Gats, 8 Western Gats, 9 Peninsular India and 2 India endemic).
- The study also identified 214 species with various local importance like raw material for local livelihood activities, plants very much associated with the wild animals and fishes for its breeding, nesting and also staple food and found to be very much useful in checking river bank erosion, stabilizing banks, and controlling floods etc. The diversity of plants having high local importance is highest in Chalakudy (137 species), followed by Periyar (135), Pampa (123) and lowest in Bharathapuzha (51species). 31 plants out of the 214 locally important species are in the IUCN threatened list (3 CR, 12 EN and 16 VU category) and 89 of them are endemic (5 Kerala, 45 Southern Western Gats, 25 Western Gats, 10 Peninsular India and 2 India endemic).

Potential species Identified for River Bank afforestation

- The study has developed a criteria for identification of species potential for future River bank afforestation programs. The parameters considered for this are: IUCN Red Listed Species (3 categories), Endemic Plants (4 categories), Medicinal value of species, Other local Importance of the species and Plants mostly growing very close to or inside the River.
- The study has identified a total of 288 species (169 trees, 43 shrubs, 54 herbs and 22 climbers) under 4 prioritised classes (14 species in the very high category, 69 in high category, 158 in medium priority and another 47 species in the low priority category)

MAJOR FINDINGS- Pandanad, Chengannur and Pandalam

The sand bar formation has been reported from Kozhencherry, Ranni, Ranni- Angadi, Ranni—Peruunad, Ranni-Pazhavangadi, Seethathodu, Thottapuzhassery, Cherukole, Koipram and Chittar Grama Panchayats. The Phenomenon of sand piping which results in the caving in soils dominated by sandy fractions damaging the terrain has also been reported from Cherukole, Thottapuzhassery, Seethathodu, Ranni- Angadi, Ranni-Pazhavangadi, Ranni and Chittar Gramapanchayaths. Muddy water carried suspended clay and silt particles and these deposits when occurred on the land had virtually closed the aeration and infiltration capacity of the soil.

Seethathodu Grama Panchayat witnessed the maximum destruction of the paddy field (86 completely and 182 partially). Siltation particularly with respect to alluvial clay, sandy deposits in certain paddy lands have affected the physico - chemical properties of the paddy lands.

- Identified 569 Angiosperms of 115 different plant Families, 5 Gymnosperms, 14 Pteridophytes and 4 Bryophytes from the three different study locations. Among the 569 Angiosperms identified 119 were trees, 114 were shrubs, 258 were herbs, 59 were climbers, 8 were lianas, 6 were vines, 4 were trailers and 1 was creeper. 205 Angiosperms, 2 Gymnosperms, 8 Pteriodphytes, and 1 Bryophytes were found in all the three locations. Others were limited to certain locations only. A total of 409 Angiosperms from Pandalam, 383 from Chengannur and 332 from Pandanad were identified respectively.
- A total of 29 grasses were identified. Majority of the grasses were collected from Pandanad. 13 aquatic Angiosperms were identified. The most abundant family was Euphorbiaceae with 38 representations.
- Total 11 endemic Angiosperm species were identified of which 5 were endemic to South India, 2 were endemic to Peninsular India, 1 each was endemic to Western Ghats, Southern Western Ghats and Southern Western Ghats Kerala region. Among the identified plants 2 Angiosperms, 1 Gymnosperm and 1 Pteridophyte were endangered and threatened. Many of these plants lost their habitat due to landslides, wind and flood.
- Invasive Weeds: The most abundant Genuses found in all the flood-affected areas were *Alternanthera sessilis, Alternanthera dentata, Merrimia hederacea, Merremia vitifolia, Ipomea cairica, Trema orientalis, Mickania micrantha, Chromolaena odorata and Lygodium flexosum.*
- A total of 142 Angiosperms, 2 Gymnosperm, 5 Pteriodophytes, and 2 Bryophytes were reported from Kadakkad Grove during a pre-flood study. In the present investigation, 10 plants of which 3 were of threatened category cannot be observed. 136 plants were identified from *Mundankavu* during the pre-flood study, but during this investigation, only 125 plants were observed in this sacred grove. A total of 21 species disappeared or were not encountered. Some new appearances of uncommon species like *Sphenoclea zeylanica* and *Xanthium strumarium* were noticed, which were not present during the previous study. A number of plants were observed to change their growth pattern to weeds. Their growth pattern also changed after the flood, especially *Alternanthera sessilis, Alternanthera dentata,* are herbs but in the flood-affected areas these plants changed their growth pattern to climbers and their number enormously increased like the common weeds.
- 17 flood level herbaceous plants, from the riverine areas of Pandalam and Chengannur, could withstand flood. They have firm and elaborate root system, which protected the soil of the catchments from erosion. Flood level resistant plants: *Auxonopus compressus, Kyllingia brevifolia, Desmodium trifolium, Cassia tora, Ludwigia ascendens, Mollugo oppositifolia, Centella asiatica, Hedyotis corymbosa, Eclipta prostrata, Elephantopus scaber, Scoparia dulcis, Hygrophila ringens, Hygrophila schulli, Boerhaavia hospita, Aerva lanaata, Polygonum barbatum, Polygonum glabrum*
- A total of 151 taxa of 6 different Classes of micro-flora were identified from different representative samples of three study locations-Pandalam, Chengannur and Pandanad.

- Among the total identified 39% were Diatoms, 23% were Charophyta, 18% were Chlorophyta, 15% were Cyanophyta, 4% were Euglenophyta, and 1% were Chrysophyta. 95 of the total phytoplankton come under general floating plankton catgory, 31 were benthic in habit, 25 of them were periphyton (epiphytic).
- From Chengannur 104 taxa were identified in the previous study, but only 94 were found during the present investigation. From Pandalam 76 taxa were identified in the previous study, but only 65 were found during the present investigation. It was found that many of the microalgae present during the previous study period was absent in the present study and the unfavorable growth of many pollution algae was noticed in some locations.
- New appearances, lost species, Indicator species: From Chengannur 2 of such phytoplankton were identified (*Pinnularia divergentissima* and *Synedra sp.*). From Pandalam 19 of such forms were identified. *P. divergentissima* is usually seen in marine habitats. The appearance of such an alga in this freshwater habitat is to be seriously considered.
- 13 Phytoplankton found in Chengannur and 19 found in Pandalam in the previous study was not seen during this investigation. Indicator species: the number of pollution Indicator species was more in Pandlam. eg : *Euglena marsonii, Euglena viridis, Euglena acus, Phacus accuminatus*etc. The appearance of *Microcystis aeruginosa* in a wetland at Pandanad is also a sign of mixing up of water of the coastal region to the inland waters during the flood. This is a toxic alga producing a hepatotoxin "microcystin".
- Indicator species: Large number of the flagellated forms in a water body indicates the organic pollution**.** *Nitzschia palea, Navicula acicularis, Gomphonema parvulum* are pollution indicator algae.
- The most abundant Genus's found in all the flood-affected areas were *Cosmarium contractum*, *Nitzchia palea* and *Pnnularia viridis*. Those algae that love the polluted atmosphere with high amount of nitrogen and phosphorus input, as different species of *Euglena* and *Phacus* were present in large numbers in some of the study sites.

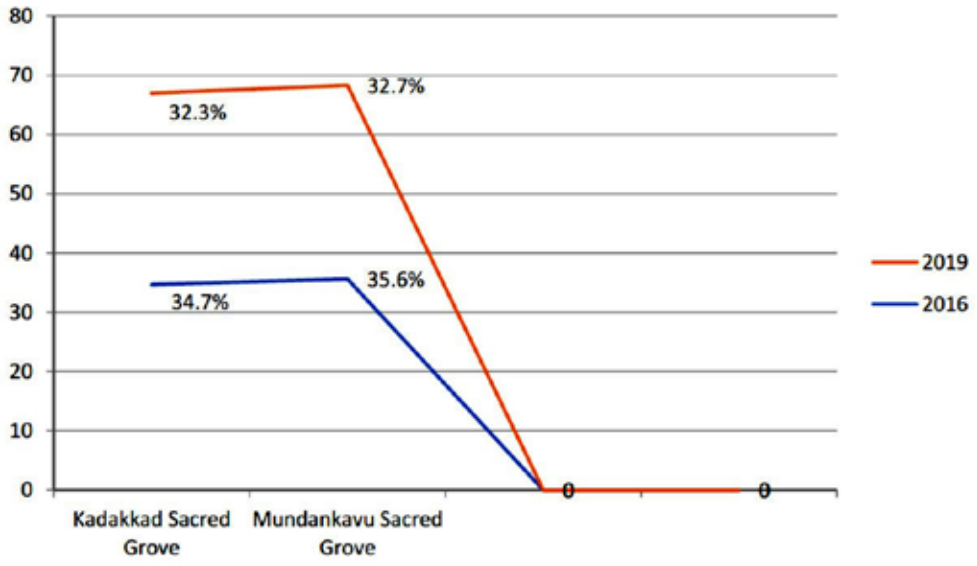

Fig. 29 Comparison of plant loss of two sacred groves- preflood and post flood

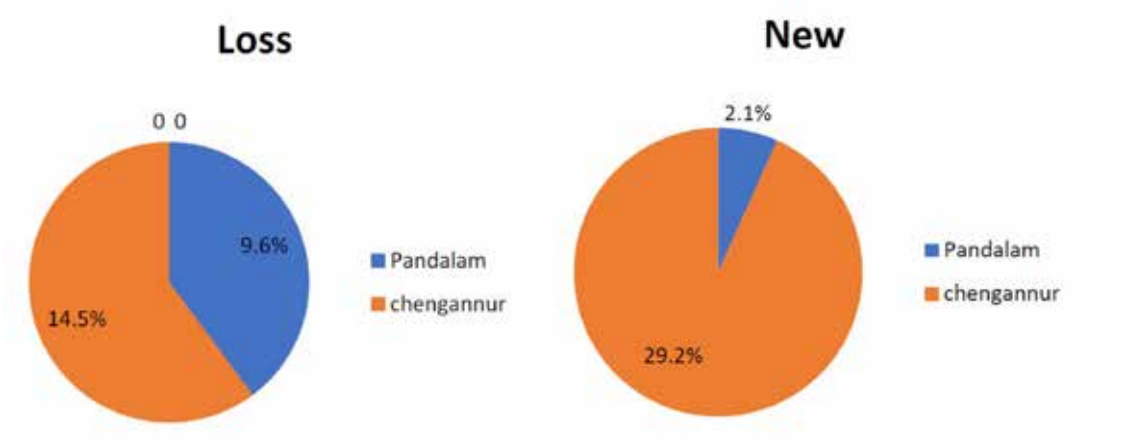

FIG. 30 Loss and appearence of micro-algae at Pandalam & Chengannur

2.5. MANIMALA RIVER

Manimala river runs through the districts of Idukki, Kottayam, Pathanamthitta and empties into the south of Vembanad Lake, Kainakary, and Alappuzha. The study was carried out from the stretch of Kainakary to Uppukulam Hills covering the distance of 91 km. The area was divided into the six segments based on vegetational change, ecological characterization, edaphological variations and the magnitude of flood 2018.

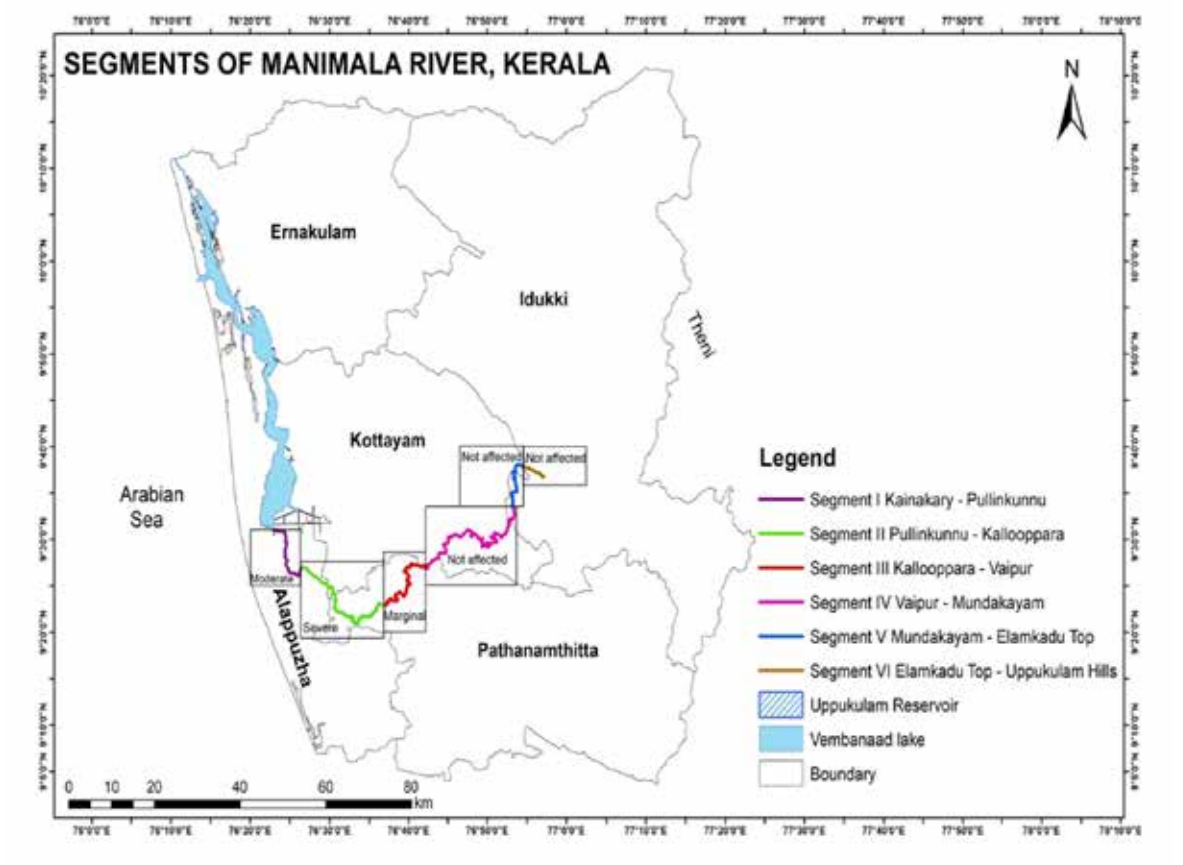

Fig. 31 Map showing a segment of Manimala river.

Distribution of flood damaged endemic plants

Key findings

1. The major edaphic changes that occurred during the flood 2018 in Manimala River was the formation of alluvial and sand bars.
2. The protection of river banks is sustained through the natural habitat of riparian flora, acting as vegetation guard. The plants like *Bambusa vulgaris, Taliparitti tiliaceum, Thespesia populnea, Ochlandra* sp. constitute as common vegetation guard species. In low lands of Kuttanad (Kainakary to Pulinkunnu) the natural vegetation guard does not exist because the area is mostly covered with manmade walls to safeguard the crop cultivation (paddy) from inundation. The Vaipur-Mundakayam area the vegetation guard are covered with floristic elements like *Ficus exasperata, Ochreinauclea missionis* and *Pandanus* sp., which grows along with water flowing areas riverside and reduce flood impact.
3. The riverine and flood plain floristic composition of Manimala River is composed of 398 species
4. The endemic species of Manimala River includes 50 species from 47 genera represented from 34 families.
5. Alteration of edaphical and ecological functions in the terrestrial transitional and aquatic zones, occurred which in turn altered the existing vegetation.
6. Invading of seedlings of swampy species *Senna alata, Xanthium strumarium, Pueraria phaseoloides* etc. is an indication of edaphic changes due to the flood and subsequent vegetational shifts.
7. The flood effect is observed maximum in the juvenile stages of tree species. Due to the flood the germination of the seed doesn't take place, which results in the decline in the rate of recruitment of these species. In the near future due to the lower rate of germination the younger trees population will be very low and can eventually cause large amount of landslip from the banks.
8. Soil silting and sand deposition was seen throughout the river bank after flood. However the sand deposition over the soil has highly affected the riverine vegetation, especially the herbaceous species, in future these may leads to selective recruitment of aggressive species.

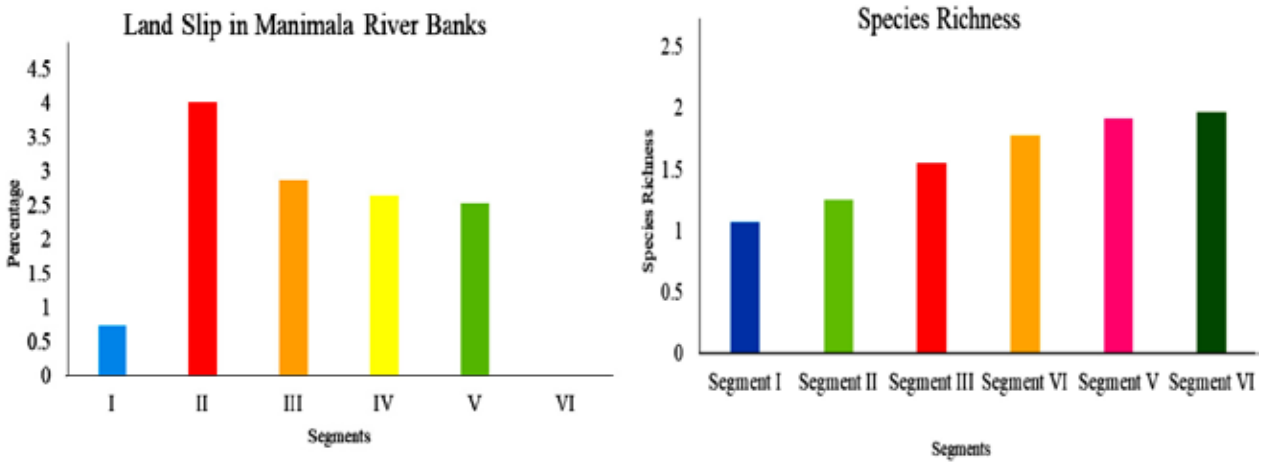

Fig. 32 Graph showing number of landslip and species richness in Manimala river banks

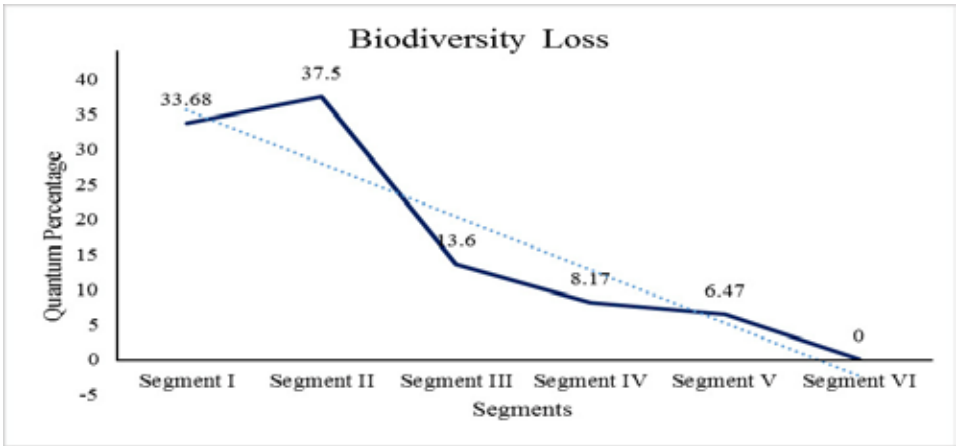

Fig. 33 Biodiversity loss in Manimala river bank

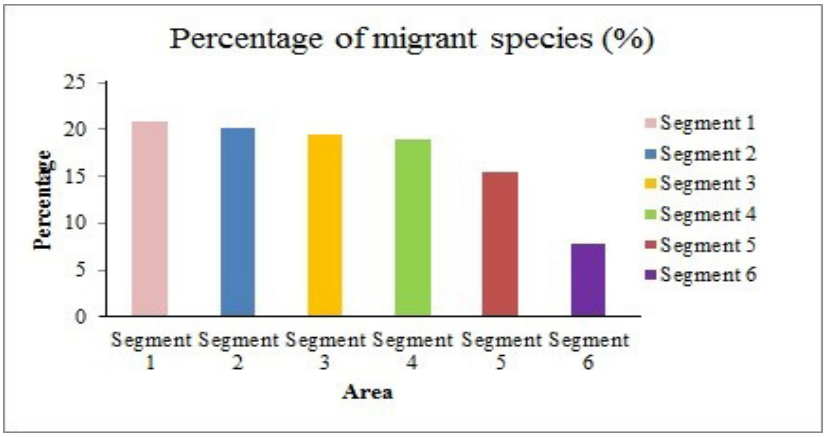

Fig. 34 Percentage of migrant species in Manimala river

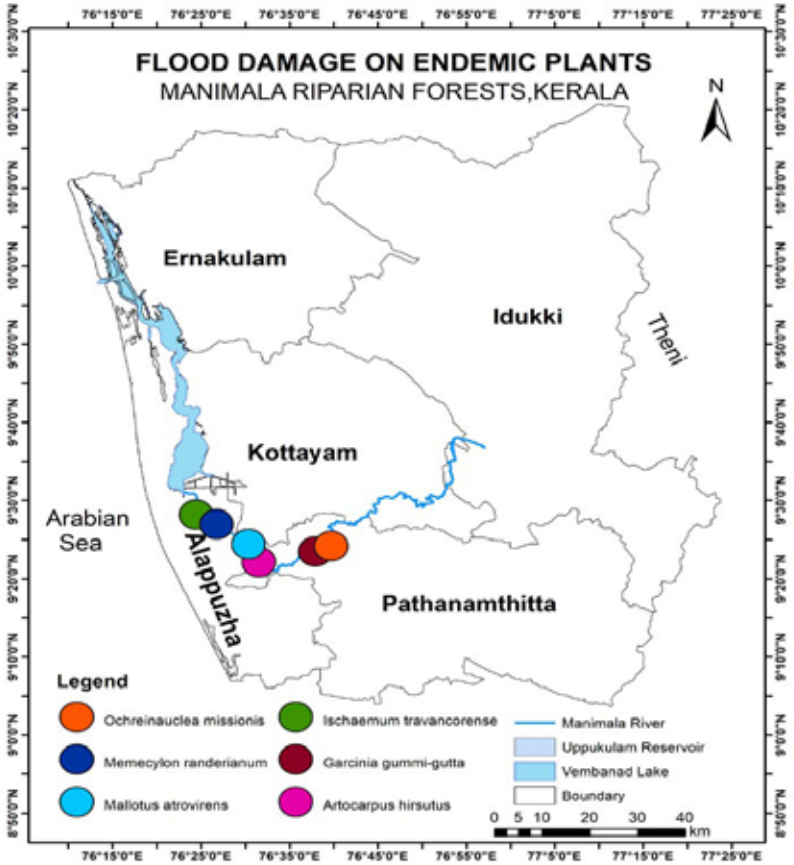

Fig. 35 Map showing flood damages on endemic plants- Manimala river

9. The flood damaged crop field is now covered with herbaceous elements like *Alternanthera sessilis*, *Mariscus javanicus*, *Gomphrena celosioides*.
10. Invasive species like *Chromolaena odorata*, *Pueraria phaseoloides* and a Poaceae member *Digitaria ciliaris* were dominant in agriculture land this may change the faunal association and have a negative impact on apiculture and dairy farm industry.
11. From the assessment of biodiversity loss during the flood, the endemic species viz. *Artocarpus hirsutus*, *Ischaemum travancorense*, *Garcinia gummi-gutta*, *Mallotus atrovirens*, *Memecylon randerianum* and *Ochreinauclea missionis* were heavily destroyed.
12. The flood disrupts floristic equilibrium (except in segment VI) a sort of homogenization of habitat and abiotic resources , buried the seeds or seedlings of existing vegetation and deposited seeds and propagules of some other species especially seeds of grasses and hedges, resulting an evenly spread of some grassy and swampy members. Segment I and II is most affected by the flood and, so the restoration programme shall be implemented with due importance to these areas. The Upper kuttanad – Segment III, is noticed with partial damage of biodiversity and heavy dumping of sand, alluvial soil, clay and non-biodegradable wastes. The accounting of species richness shows that the non affected segment VI is having the highest value followed marginally affected segment V. The eco-restoration programme may concentrate in the most affected area that is Pulinkkunnu to Kallooppara.
13. River bank protection can be enhanced with the native species like *Pandanus furcatus, Talipariti tiliaceum*, *Thespesia populnea*, *Ochlandra* sp., *Ficus exasperata*, *Ochreinauclea missionis* that can be used for vegetation guard programme. These species are spreading across watered area rather than to terrestrial areas. This mode of growth and spreading stilt root system would make the banks more resistant to flood with enhanced soil anchorage.
14. The guard vegetation may be strengthened with endemic species *Hydnocarpus macrocarpa, Humboldtia decurrens, Vateria indica, Hopea erosa, Cinnamomum perrottetii.*
15. The species like *Talipariti tiliaceum*, *Thespesia populnea*, *Ochlandra* sp., *Ficus exasperata*, *Ochreinauclea missionis* are found resistant against the flood due to the webbing of the stilt roots, while the *Bambusa vulgaris* reed due to adventitious root system fail to be a good barrier against the flood, instead it can cause much worse scenario by blocking the water flow and deposition in the river water which will in turn become waste deposition.
16. The flooding has affected the natural microbiota of the soil as revealed by culture dependent and independent (metagenomic) analysis. There is an increase in the anaerobic microorganisms and pathogenic fungal species in the flood affected soil than that of non-flooded areas. There is a depletion in soil enzyme activity compared to buffer and non-flooded areas indicating that there is a decrease in beneficial organisms in the soil (nitrogen fixing and phosphate solubilising).

Table 7. List of Endemic Plants in Manimala Riparian Forests, Kerala

SL. No	Botanical Name	Family	*Habit	Remarks
1	*Actinodaphne malabarica* N.P. Balakr.	Lauraceae	T	No damage
2	*Ancistrocladus heyneanus* Wall. ex J. Graham	Ancistrocladaceae	CS	No damage
3	*Arenga wightii* Griff.	Arecaceae	T	No damage
4	*Artocarpus hirsutus* Lam.	Moraceae	T	Absense of seedlingsmay be due to carry away by water current.
5	*Bentinckia condapanna* Berry ex Roxb.	Arecaceae	T	No damage
6	*Biophytum congestiflorum* Govind.	Oxalidaceae	H	Partially damaged with water current
7	*Calamus vattayila* Renuka	Arecaceae	CS	No damage
8	*Cinnamomum perrottetii* Meisn.	Lauraceae	T	No damage
9	*Cinnamomum sulphuratum* Nees	Lauraceae	T	No damage
10	*Connarus parameswaranii* Ram. &Raj.	Connaraceae	CS	No damage
11	*Cullenia exarillata* A. Robyns	Malvaceae	T	No damage
12	*Cycas circinalis* L.	Cycadaceae	S	No damage
13	*Dimorphocalyx beddomei* (Benth.) Airy Shaw	Euphorbiaceae	T	No damage
14	*Diospyros bourdillonii* Brandis	Ebenaceae	T	No damage
15	*Drypetes malabarica* (Bedd.) Airy Shaw	Euphorbiaceae	T	No damage
16	*Euphorbia vajravelui* Binojk. & N.P. Balakr.	Euphorbiaceae	S	No damage
17	*Garcinia gummi-gutta* (L.) Roxb.	Clusiaceae	T	Affected with landslip
18	*Grewia umbellifera* Bedd.	Tiliaceae	CS	No damage
19	*Gymnostachyum canescens* (Nees) T. Anderson	Acanthaceae	S	No damage
20	*Helicanthus elastica* (Desr.) Danser	Loranthaceae	S	No damage
21	*Holigarna arnottiana Hook.f.*	Anacardiaceae	T	Absence of seedlings may be due to carry away by water current
22	*Holigarna beddomei Hook.f.*	Anacardiaceae	T	Absence of seedlings may be due to carry away by water current
23	*Hopea erosa (Bedd.) Slooten*	Dipterocarpaceae	T	No damage
24	*Humboldtia bourdillonii Prain*	Fabaceae	T	No damage
25	*Humboldtia decurrens Bedd. ex Oliv.*	Fabaceae	T	No damage
26	*Humboldtia vahliana Wight*	Fabaceae	T	No damage
27	*Hydnocarpus macrocarpa Warb.*	Flacourtiaceae	T	No damage
28	*Impatiens verticillata Wight*	Balsaminiaceae	H	No damage
29	*Ischaemum travancorense Stapf ex C.E.C.Fisch.*	Poaceae	H	Submerged with water inundation and no sprouting out.
30	*Ixora johnsonii Hook.f.*	Rubiaceae	S	No damage
31	*Jasminum malabaricum Wight*	Oleaceae	STG	Partially damaged with water current
32	*Mallotus atrovirens Wall. ex Müll.Arg.*	Euphorbiaceae	S	Physical damage including dumping off.
33	*Medinilla malabarica Bedd.*	Melastomataceae	S	No damage

34	*Memecylon randerianum S.M.Almeida & M.R.Almeida*	Melastomataceae	S	No damage
35	*Miquelia dentata Bedd.*	Icacinaceae	S	No damage
36	*Myristica malabarica Lam.*	Myristicaceae	T	Seedlings absent
37	*Ochlandra scriptoria (Dennst.) C.E.C.Fisch.*	Poaceae	H	Partially damages with uprooting
38	*Ochreinauclea missionis (Wall. ex G.Don) Ridsdale*	Rubiaceae	T	Partially damages with uprooting
39	*Osbeckia leschenaultiana DC.*	Melastomataceae	S	No damage
40	*Premna glaberrima Wight*	Verbenaceae	CS	Damaged at different-degree and magnitude
41	*Psychotria nilgiriensis Deb & M. Gangop. var. nilgiriensis*	Rubiaceae	S	No damage
42	*Pterospermum reticulatum Wight & Arn.*	Sterculiaceae	T	No damage
43	*Schefflera bourdillonii Gamble*	Araliaceae	T	No damage
44	*Solena amplexicaulis (Lam.) Gandhi*	Cucurbitaceae	CS	No damage
45	*Stephania wightii (Arn.) Dunn*	Menispermaceae	CS	No damage
46	*Strobilanthes lawsonii Gamble*	Acanthaceae	S	No damage
47	*Syzygium laetum (Buch.-Ham.) Gandhi*	Myrtaceae	T	No damage
48	*Syzygium mundagam (Bourd.) Chithra*	Myrtaceae	T	No damage
49	*Torenia bicolor Dalzell*	Scrophulariaceae	H	Highly damaged and re-placed with some other species
50	*Tylophora mollissima Wall. Ex Wight & Arn.*	Asclepiadaceae	TW	No damage

**Habit: H- Herbs; S- Shrubs; CS – Climbing Shrubs; STG – Stragglers & T- Trees*

3 IMPACT OF FLOOD ON MANGROVE ECOSYSTEM OF MANGALAVANAM, PATHIRAMANAL, PALLIPUARAM, PERUMBALAM

Mangrove crabs are ecologically significant in many ways as they keep much of the energy within the forest by burying and consuming leaf litter. Burrows are the primary indicators in the mangrove ecosystem to denote the presence of crabs. Crab faeces may form the basis of acoprophagous food chain contributing to mangrove secondary production such as food for juvenile fish inhabiting the adjacent waterways indicating that crabs also help near shore fisheries.The findings of this study support the hypothesis that mangrove crabs may function as keystone species in the ecosystem.

- Significant differences were observed between the "undisturbed" (Mangalvanam Birds Sanctuary and Kadalundi Birds Sanctuary) and disturbed (Puthuvypin, Kadamakkudy and Kallai) mangrove areas in terms of quantity and quality in flora/ fauna of mangrove ecosystem.
- The mangroves of Ernakulam district had high species richness, with monospecies dominance in particular geographical locations.
- The species like *Avicennia marina* located in Puthuvypin, *Avicennia officinalis* of Mangalavanam Birds Sanctuary, *Sonneratia caseolaris* of Kadamakkudy geographical area. The Mangroves in other district (Kadalundi Birds Sanctuary and Kallai) have comparatively low monospecies distribution. Promoting the recovery of the monospecies dominant area should be given long term priority.
- The density of fishes, crabs and gastropods as "indicator species" in all study locations (Mangalvanam Birds Sanctuary, Puthuvypin and Kadamakkudy of Ernakulam district and Kadalundi Birds Sanctuary and Kallai river areas of Kozhikode district) are reduced significantly to a greater extent. This should be monitored long term.
- The indicator animals like fishes, crabs, and molluscs are mainly available in protected mangrove areas when compared to other local mangrove forests due to various environmental threats.

MAJOR FINDINGS

3.1 Mangalavanam

✓ Mangalavanam is a small mangrove area located in the middle of Ernakulam City comprising of a shallow tidal pond in the centre with its edges covered with thick mangrove vegetation. Most of the floral species are either mangrove species or those that can tolerate frequent saltwater / brackish water inundations. A total of six species

from three families of mangroves viz., *Avicennia officinalis* (Family: Avicenniaceae), Rhizophora mucronata and Rhizophora apiculata (Family: Rhizophoraceae), *Bruguiera cylindrica* and *Bruguiera gymnorizha* (Family: Rhizophoraceae), and Acanthus ilicifolius (Family: Acanthaceae) which belonged to 6 genera and 4 families were recorded from the Mangalavanam mangrove wetland.

- ✓ Some of the local fishes, fiddler crabs (Ucasp), red crab (Sesarmasp) frequently observed in Mangalvanam Birds Sanctuary in 2015-2017, were reduced during the survey period from January to March 2019.
- ✓ The survey showed noticeable lack of molluscs / gastropods indicator species in all the selected plots. Only in a single selected plot in Mangalvanam Birds Sanctuary, where flow of water out is more; the survey could observe few species of gastropods and bivalves .
- ✓ There is no flow of water in the lake inside the middle of the Mangalvanam Birds Sanctuary. Stagnant water –by default- gets polluted, thereby proving extremely harmful to the marine life inside the water.

3.2 Puthuvypin

- ✓ Puthuvypin mangrove formation situated towards the southern end of Vypeen-Njarakkalbelt, is considered to be the largest single stretch of mangroves in southern Kerala. Though sporadic and interspersed with settlements, the mangrove stretch extending from Vallarppadam to Njarakkal and beyond has a significant assemblage of lagoons, backwater channels, marshes and associated mangroves thickets. The area is noteworthy for its species richness and diversity, regeneration and near absence of invaded weeds and is called as potential mangroves. The close proximity of Kochi city and to the international sea route Puthuvypeen has attracted huge investment projects in the near past like the Liquefied Natural Gas (LNG) Terminal, Bunkering Terminal, Single Buoy Mooring, Ship Repair Complex, to name a few.
- ✓ The top of mangrove trees in Puthuvypin were seen to be dying.The indicator species (fishes, crabs and gastropods) were not visualized during the survey. The density of crabs and its burrows were not seen. Therefore, there is a pertinent need to carefully evaluate the prevailing environmental conditions of the development area and surroundings prior to the implementation of the development projects

3.3 Kadalundi Bird Sanctuary

- The mangrove flora of Kadalundi-Vallikunnu Community Reserve comprises about 6 true mangrove species belonging to 5 families (Myrsinaceae, Avicenniaceae, Rhizophoraceae, Euphorbiacea and Sonneratiaceae). Family Avicenniaceae is the largest family in Kadalundi-Vallikunnu Community Reserve with two species Avicennia officinalis followed by the family Rhizophoraceae having species of *Bruguiera cylindrica* and *Rhizophora mucronata*.
- Mass deposit of sand in the wetland, close to the bar mouth, has been a serious threat to the mangrove stands, resulting in the restricting of roots and consequent death of some trees of *S. alba* and *A. officinalis*.
- In Kadalundi Bird Sanctuary a unique difference in true mangrove *Bruguiera cylindrica* with orange fruit color instead of green which was observed in other mangrove areas.

- Diversity of R.mucronata and A.officinalis were prioritized as these species are regarded as salt tolerant pioneers and light demanders and possess adaptive characters for reproduction and survivial.

3.4 Kallai of Kozhikode district

- ✓ Considerable stretch of both Kallai and Chaliyar riversides along their upriver courses from the estuaries, exhibits highly disrupted strip or fringe mangroves of varied structural configuration from shrubby thicket to woody vegetation. These patches are mostly predominated with the species *Avicennia marina* and *Avicennia officinalis* with an admixture assemblage of other halophytic plants in varied stages of growth, even with secondary level succession or stunted appearance
- ✓ In the Kallairiver, the natural process of alluvial sediment transport/deposition in the estuarine habitat has practically ceased because of the ubiquitous practice of dumping large number of timber by the saw-mills located on either side of the river banks. They dump tons and tons of commercial timbers in the river stretch, considerably blocking the sediment transport to the river estuary. Ths study was unable to trace any of the indicator species in this mangrove ecosystem owing to varied kinds of pressures from urban settlements, port developmental and other industrial activities.

3.5 Kadamakkudy

- ✓ *Sonneratia caseolaris*, commonly known as mangrove apple a species of plant in the family of Lythraceae, are the dominant species in Kadamakkudy. The largest population of this species is observed in this geographic area.
- ✓ There is a severe decline of crab, fishes and prawn cultivation after the Kerala flood in Kadamakudy.
- ✓ Due to rapid urbanization most of mangrove flora are under severe threat due to samll size, isolation of species in patches

Microbial phyla

- The overall effect of flood on soil communities when compared to the pre-flood data is that the total reads and amount of DNA was less in the flood affected samples. The Kallai and Kadalundi samples contain bulk reads in congruence to the pre flood data of Mangalavanam. Many microbial phyla which were prominent in Pre flood analysis were found missing in the post flood analysis. Acidobacteria, Chlorobi, Chloroflexi, Cyanobacteria, Euryarchaeota, Nitrospirae, Spirochaetes, Verrucomicrobia were missing from Mangalavanam mangrove. The loss of microbial diversity of Puthuvypin will have a long term impact on the biodiversity of this area.
- The heavy metal concentrations of all the survey area were high. The least number of diversity of plants, increased shrimp culture and high heavy metal concentration in Kadamakkudy mangrove hinds to biomagnification and its hazards in the environment.
- The increased Vibrio population in Kadamakkudy region is expected to have a high socio economic impact. Since this is an area of extensive aquaculture, there will be high occurrence of Vibrio infections in the aquaculture farm leading to huge economic loss.

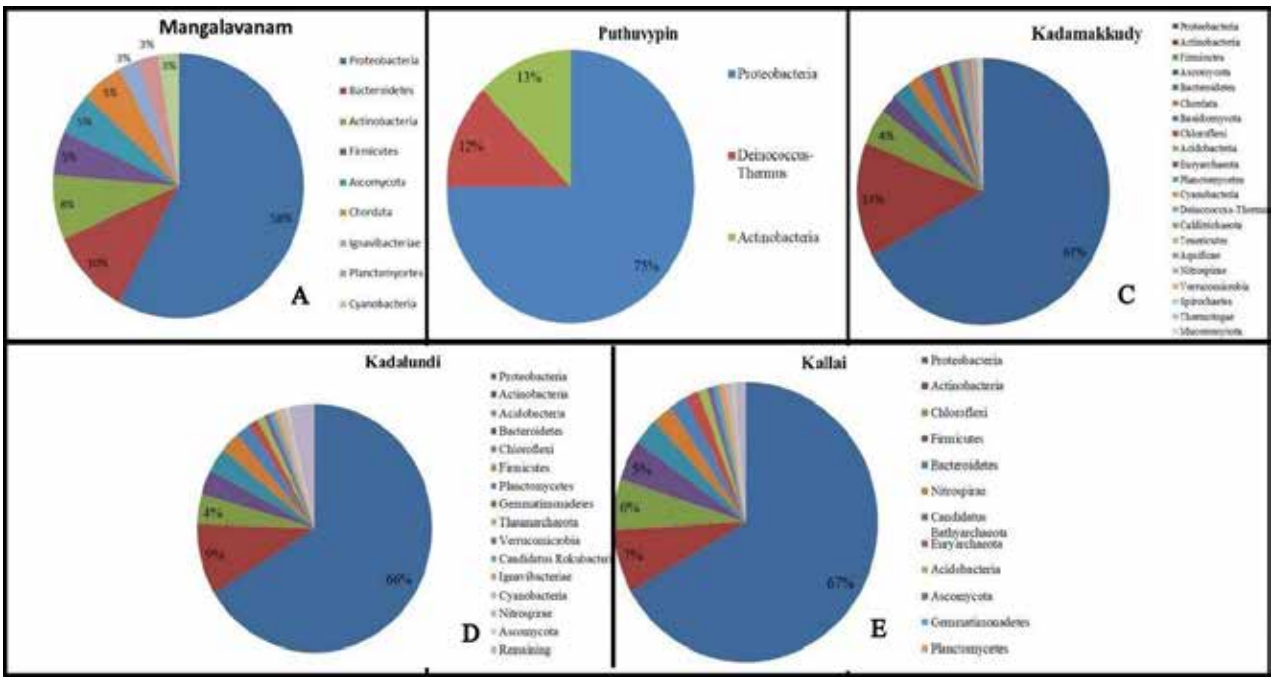

Fig. 36 Comparison of phylum level distribution of A) Mangalavanam, B) Puthuvypin, C) Kadamakkudy, D) Kadalundi and E) Kallai mangroves

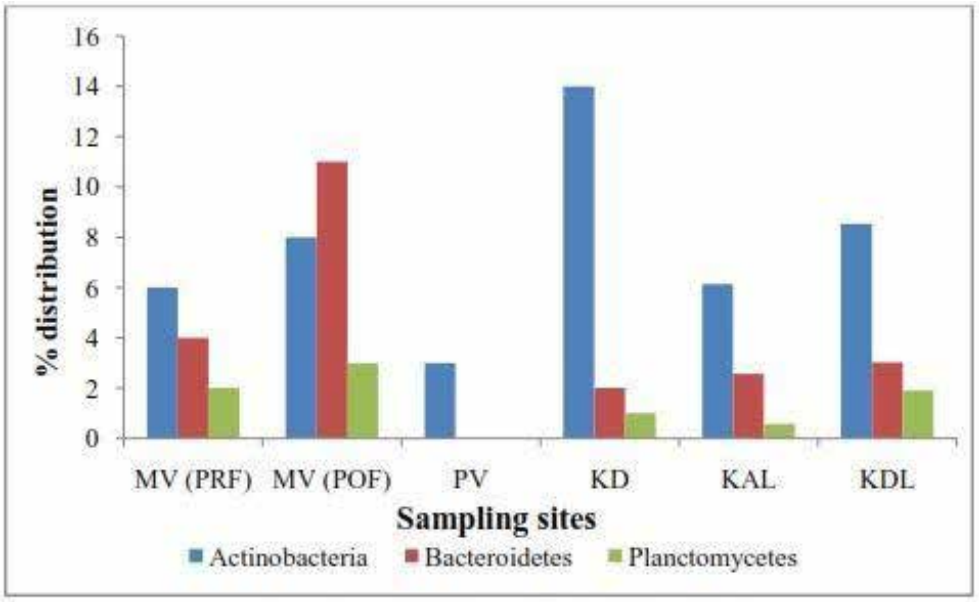

Fig. 37 Distribution of Selected microbial phyla of A) Mangalavanam, B) Puthuvypin, C) Kadamakkudy, D) Kadalundi and E) Kallai mangroves

4 IMPACT OF FLOODS ON SELECTED FAUNAL SPECIES

4.1 FISH DIVERSITY OF BHARATHAPUZHA PERIYAR, CHALAKUDY, PAMPA AND ACHANKOVIL

In the upstream area Riverbed showed no mentionable alteration in the case of River Bharathapuzha, Periyar and Pamba. In the mid-stream areas and downstream areas, location specific alterations were observed. In river Bharathapuzha, in many regions like Melepattambi, Pulamanthol, Thirunavaya, and Ponnani unusually large sand bars were formed following flood. In Chamravattom region the sand bars formed badly interrupted the movement of fishermen. In the mid stream and lower stream areas, there was considerable alteration in the river bed, like deposit of sand or silt or debris. In some areas the depth was reduced, in other areas sand/gravel bottom was replaced by silt and mud. Some areas were blocked by debris, plastic and discarded cloth etc. As far as the fresh water fishes are concerned, most of the habitat specialists inhabit the hill streams and hence they are not affected. In lower stretches, in connection with river bed alterations resident species were replaced, some species disappeared and some new species not found earlier were located. In lower regions except few, most of the fish species are generalist species which do not require any specificity in the habitat and can survive in a wide range of water quality conditions and habitat. Another interesting observation was that some species endemic to one river was observed in other river systems too. During the flood when all the river water become one fished moved from one river system to another and established there.

The Western Ghats Biodiversity Hotspot harbours extremely high levels of endemism for freshwater-dependent taxa such as crabs (92%), amphibians (87%), shrimps (69%) and fish (59%) with majority of endemic species restricted to the southern region of Western Ghats within the state of Kerala. Comprehensive field surveys were carried out in four of the major river systems affected by floods, viz, Periyar, Chalakudy, Pampa and Achankovil. In addition, micro-habitat-based surveys were carried out in the six critical freshwater fish habitats including Periyar Tiger Reserve, Valparai, Malakkapara, Santhampara, New Amarambalam and Shenduruney Wildlife Sanctuary to determine the abundance, population status and impacts to the habitats of the 'single-location fish species'. Thireteen species are narrow endemics known to occur only in single locations, in peculiar microhabitats and all these species are categprized as threatened on the IUCN red list.

FISHES OF RIVER BHARATHAPUZHA

Bharathapuzha is considered as one of the richest source of aquatic biodiversity including fish, molluscs and odonates. About 116 species of fishes has so far been reported from Bharathapuzha with three species being endemic to the river. Among the fishes studied, 33species was found to be endemic to Western Ghats. About 12% of the fishes of Bharathapuzha is considered as threatened. Commercial fishery was supported by fifty seven species recorded in this study.

In the present study, the survey in the Bharathapuzha revealed the presence of 41 species of fishes. There are fifteen indigenous species (37%), and 8 species endemic to India. Considering the threat status, fishes of Bharathapuzha there is only one species classified as critically endangered, 5 are among endangered (23%), three species are near threatened (7%), one species is vulnerable three are under near threatened category and twenty three (63%) are among least concerned

Fishes of River Periyar

The total number of fishes observed in the survey of River Periyar is 23 included in six orders and 11 families. Among the twenty three species, about half (10species) of fishes are endemic to Western Ghats, seven species are indigenous, two species are endemic to Kerala and two species are endemic to Indian sub continent and one species was endemic to India. Among the 23 species of fishes collected from river Periyar only one species- *Oreochromic mossambicus* was found to be exotic. Among the fishes of Periyar, one species viz., *Torkhudree* is listed under endangered category. Three species were found to be vulnerable and two near threatened. Most of the fishes (76%) were under least concerned category ,

Fishes of River Pampa

River Pampa has a total piscine representation of 21species. One species *Garra surendranathini* was found to be endemic to Kerala. *Oreochromis mossambicus* and Gambusia species are the two exotics collected from River Pamba. Among the fishes reported in the River Pampa, three were categorised as endangered, two as near threatened and one as vulnerable. Twelve species are considered as least concerned.

Key findings

1. Populations of all endemic species and threatened species occurring in the above mentioned locations appeared to be stable and comparable to previous studies carried out in 2000 and 2017. All population seem to show resilience.
2. The Kerala floods had much of their impacts on the riverine microhabitats located in the middle and lower reaches of the major river systems affected by floods. The morphology of many middle and lower reach fish habitats has been severely affected and many have been transformed beyond recognition. There has been serious depletion of in-stream and riparian cover in rivers such as Periyar, Chalakudy and Achankovil.
3. Shoreline vegetation and riparian cover has been significantly affected in the lower reaches of Periyar River especially in the areas around Malayatoor which were critical habitats for species such as the Malabar Puffer, *Carinotetraodon travancoricus* and the freshwater Pipefishe, *Microphis cuncalus.*

4. The catastrophic floods in August 2018 resulted in the first-ever records of several additional alien species from natural waters of this biodiversity hotspot revealing the existence of an unregulated, unscientific, mostly illegal and thriving aquaculture and aquarium fisheries sector based on alien species, especially along the riverine floodplains.

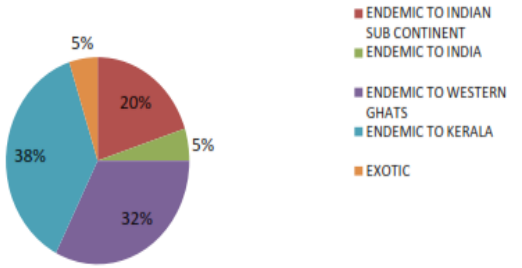

Fig. 38 Endemism among fishes of Bharathapuzha river.

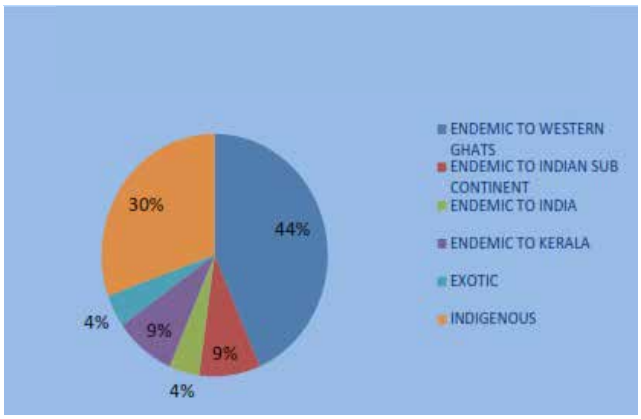

Fig. 39 Endemism among fishes of Periyar river.

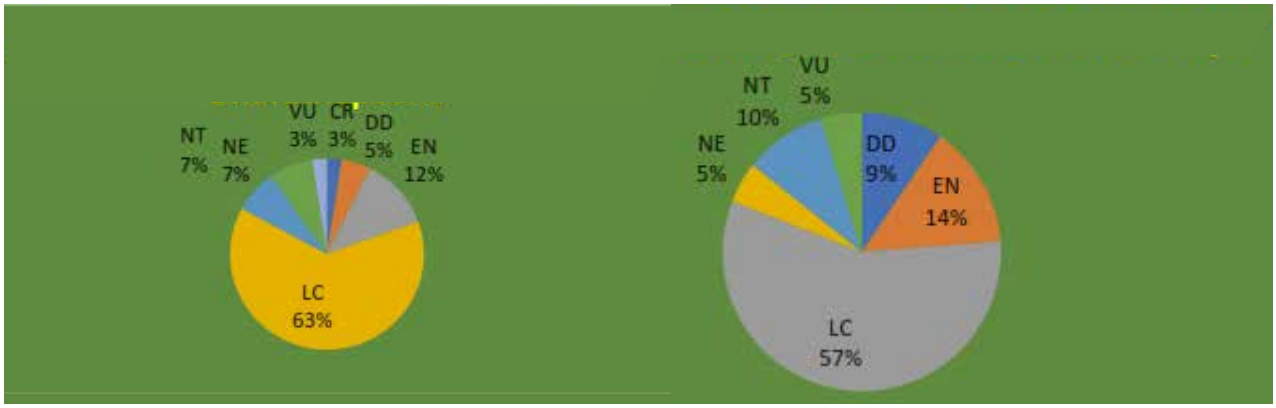

Fig. 40 IUCN catogory of fishes - Bharathapuzha river

Fig. 41 IUCN catogory of fishes - Periyar river

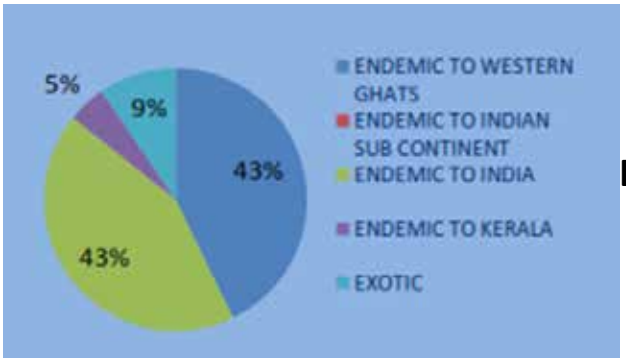

Fig. 42 Endemism among fishes- Pampa river

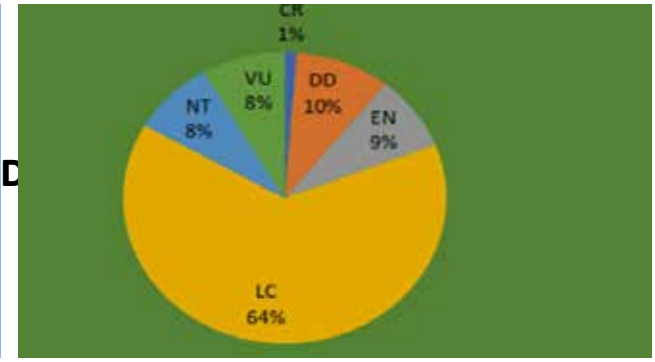

Fig. 43 IUCN catogory of fishes- Pampa river

Table 8. List of narrow endemic species, their IUCN Red List Status and location

Species	IUCN Status	Only known location/River System
Dawkinsia exclamatio	Endangered	Shenduruney Wildlife Sanctuary/Kallada
Eechathalakenda ophicephalus	Endangered	Periyar Tiger Reserve/Periyar
Garra periyarensis	Vulnerable	Periyar Tiger Reserve/Periyar
Ghatsa santhamparaiensis	Endangered	Santhampara Hills/Periyar
Ghatsa montana	Endangered	Malakkapara/Chalakudy
Glyptothorax davissinghi	Endangered	New Amarambalam/Chaliyar
Glyptothorax housei	Endangered	Valparai/Chalakudy
Horalabiosa arunachalami	Critically Endangered	Santhampara Hills/Periyar
Hypselobarbus periyarensis	Endangered	Periyar Tiger Reserve/Periyar
Lepidopygopsis typus	Endangered	Periyar Tiger Reserve/Periyar
Mesonoemacheilus periyarensis	Vulnerable	Periyar Tiger Reserve/Periyar
Mesonoemacheilus menoni	Vulnerable	Periyar Tiger Reserve/Periyar
Tariqilabeo periyarensis	Endangered	Periyar Tiger Reserve/Periyar

Table 9 Catch per effort of single location endemic species (pre and post flood)

Species	Location	Catch per effort (pre-flood)	Catch per effort (post-flood)
*Dawkinsia exclamation**	Shenduruney	7	5
*Eechathalakenda ophicephalus**	PTR	2	2
*Garra periyarensis**	PTR	6	7
Ghatsa santhamparaiensis#	Santhampara	0.5	1
Ghatsa montana#	Malakkapara	0.25	0.5
Glyptothorax davissinghi#	NARF	2	3
Glyptothorax housei#	Valparai	1	0.25
Horalabiosa arunachalami #	Santhampara	0.5	0
*Hypselobarbus periyarensis**	PTR	12	15
*Lepidopygopsis typus**	PTR	9	11
Mesonoemacheilus periyarensis#	PTR	10	12
Mesonoemacheilus menoni#	PTR	7	4
*Tariqilabeo periyarensis**	PTR	2	1

4.2 BIRDS, BUTTERFLIES, ODONATES, AND AMPHIBIANS

Impact of floods on selected faunal species namely Birds, Butterflies, Odonates, and Amphibians were studied in ::

1. Kattampally Wetlands (Kannur)
2. Pookode Lake (Vythiri, Wayanad)
3. Pullu Kole Wetlands (Thrissur)
4. Vazhachal Forest Division (Thrissur)
5. Nedumudi (Vembanad, Alappuzha)
6. Melepadam (Upper Kuttanad, Alappuzha)
7. Vandiperiyar (Periyar Tiger Reserve, Idukki)
8. Chalakudy River Basin

- The key sightings in Kattampally Wetlands included Isabelline wheatear a rare migratory species, Shaheen Falcon, Western Marsh Harrier. 53 species of odonates were documented including Lyriothmis acigastra, an indicator species with very limited flight season after the onset of monsoon.
- 85 species of birds were recorded from Pookode Lake situated in Vythiri Taluk in Wayanad district including Malabar Trogon, Orange-headed and Thrush, Black-winged Kite, 25 species of Amphibians were recorded including Raorchestes ochlandrae a species specially adapted to live on reeds of Ochlandrae. Uperodon triangularis, a species of burrowing narrow mouthed frog endemic to Western Ghats and Rhacophorus lateralis the smallest tree frog species endangered and endemic to Western Ghats were sighted. 52 species of odonates including Hemicordulia asiatica, an endemic dragonfly species were reported.
- From Kole Wetlands 76 species of birds including Black-winged Stilt, Ruddy-breasted Crake, Blue-tailed Bee-eater, 8 species of amphibians including Euphlyctis karaavali, 31 species of odonates including Paracercion calamorum was recorded.
- From Vazhachal Forest Division 76 species of birds including Great Hornbill, Malabar Pied Hornbill, 69 species of butterflies and 56 sps of odonates including Merogomphus tamaracherriensis, an endemic dragonfly species was recorded. 28 species of amphibians including Mercurana myristicapalustris a species limited to Myristica swamps south of Senkottai gap which was reported for the first time from Vazhachal.
- Nedumudi Wetlands is part of the Vembanad - Kole Ramsar Site. The habitat consists of paddy-fields, isolated forest patches, sacred groves and freshwater swamps and 70 species of birds, 7 species of Amphibians, 18 species of butterflies and 21 sps of odonates were recorded.
- Melepadam - Wetlands lies between two rivers i.e. Achankovil River to the south and Pamba River to the north. 74 sp of birds were recorded including a good population of Purple Heron
- that makes nest in the reeds. The numbers indicate that they have survived flood. 14 species of butterflies, 25 species of odonates were recorded.
- Vandiperiyar - PTR : The area chosen for the study was along the Tengangi Ar and 78 bird species, 71species of butterflies, 44 sps of odonates and 24 species of Amphibians were recorded. Macromidia donaldi is a first record of the species from Periyar Tiger Reserve.
- Major findings
- To study the impact of floods on resident birds, the data acquired from the current study was compared to the data documented in e-bird in the previous years (from 2015 onwards). For this purpose, four species of resident birds were chosen for the study.

    1. Cotton Pygmy Goose (*Nettapus coromandelianus*)
    2. Lesser Whistling Duck (*Dendrocygna javanica*)
    3. Indian Cormorant or Indian Shag (*Phalacrocorax fuscicollis*)
    4. Purple Heron (*Ardea purpurea*)

- The results from the analysis indicate that the flood has not affected the resident birds as their population has not shown much variation in 2018 as compared to previous years. Cotton Pygmy Goose (Nettapus coromandelianus) a resident duck species has shown steady decline since 2015. By comparing the data from Heronry Count, Asian Waterbird Census and e-bird for the past five years, it's estimated that Cotton Pygmy-Goose has a decline of 40%. The decline is not an effect of the floods of 2018, but many other anthropogenic factors including habitat destruction, loss of nesting area etc.
- Indian Cormorant or Indian Shag (Phalacrocorax fuscicollis) is one of the bird species that shows a steady increase in their population over the last few years. This may be because they are capable of nesting in large numbers close to human habitations.
- Purple Heron (Ardea purpurea) are known to roost and nest among reeds in wetlands and the population of this species is comparatively unaffected by flood.
- The current study documented nesting behavior of Red-wattled Lapwing (Vanellus indicus), Black-winged Stilt (Himantopus himantopus) and Purple Heron (Ardea purpurea). (Upper Kuttanad).
- Amphibians are the best known biological indicators. The presence of indicator species like Mercurana myristicapalustris and Nasikabatrachus sahyadrensis was used primarily to understand the impact of flood and also others like Euphlyctis sp., Raorchestes and Indosylvirana.
- Mercurana myristicapalustris is a species of arboreal frog that descent to breed from late May to early June. This is a monotypic Rhacophorid species which is endemic to the Western Ghats. The range of the species is limited to the Myristica Swamps south of Shenkotta gap. The frog is documented to live in canopy of Myristica Swamps. The current study recorded the species from Vazhachal, Thrissur. This is a new range extension record of almost 250 kms from the currently recorded range of the species. The study recorded 15 individual males and four females from a transect of 50 mts.
- Nasikabatrachus sahyadrensis: Good numbers of tadpoles were documented in each stream, indicating that the breeding population of the species is stable at these sites. Pseudophilautus and Raorchestes species are recorded in good numbers from much of the study area, indicating a healthy and stable population.
- Only Raorchestes ochlandrae was documented in lesser numbers in transects compared to previous observations. This is largely because the Ochlandrae reed have died off following its flowering couple of years ago.
- The study also documented the late breeding of H. tigerinus - the breeding started by late July 2019 in most of the study area.
- There was a considerable reduction in number of Indirana frogs documented at Pookode during transect survey, though there were considerably good numbers sighted from the forests nearby. The change in diversity and abundance at Pookode maybe because of the paving of interlock tiles in the trek path around the Lake.
- Butterflies are quick to react to minor changes in the environment making them good ecological indicators. The diversity of butterflies had notable reduction, which could be an impact of the flood. As the study progressed from January to August 2019, the diversity and abundance of butterflies showed a steady increase; this can be largely for the fact that the diversity and abundance are higher in August as this coincides with the flight season for majority of the species. The population and diversity of butterflies belonging to Lycaenidae and Hesperiidae is noted to have considerable decline till August 2019. The diversity of species belonging to these families was

quite too low in Pookode, Vazhachal and Vallkadavu, while it is also noted that certain species like Dark Grass Blue and Ceylon swift were sighted in large numbers in low altitude wetlands. Butterflies like Chocolate Pansy, Peacock Pansy and Grey Pansy that were usually sighted in good numbers in both wetlands and midland forests prior to the flood had notable reduction in numbers during the initial surveys. Towards the end of the study, the diversity and abundance of butterflies belonging to Papilionidae, Pieridae and Nymphalidae showed steady increase, both in diversity and abundance. The experts are of the opinion that the flood could have resulted in the destruction of egg and larval from of many of the butterfly species.

- It was noted that the butterflies sighted soon after the flood were smaller in size, maybe for the reason that the larval forms of many of the species could not take proper feed. The reasons for the reduction in diversity and abundance of Lycaenidae and Hesperiidae is largely for the fact that Lycaenidae have relatively smaller larvae and hence their chances for being washed down in torrential rain and flood are more. While much of the Hesperiidae have their host plants in grasses, palms and bamboos, all of them are prone to impact of flood for the lesser shelter they can offer to the egg and larval forms that thrive on it.
- At certain sites like Pookode, Kattampally and Vembanad, more than the flood impact, the unscientific constructions and anthropogenic activities have impacted the population of the butterflies. The unscientific construction at Pookode has led to decrease in diversity and abundance of butterflies. Only 73 of the previously recorded 88 species could be documented during the study.
- The land filling in Kattampally has directly impacted the study as part of study area was altered during the course of the study. The land filling will lead to destruction of many of the host and nectaring plants.
- The burning of paddy fields in Upper Kuttanad and Vembanad has impacted the study as well, as many of the larval, egg, pupae forms of butterflies belonging to Hesperiidae family might have been destroyed during the large scale burning of paddy fields.
- Odonates have a significant role as biodiversity indicators, biocontrol agents of vectors and water quality indicators. The heavy rains, flood, soil erosion and movement of sediments have affected the larval population of Odonates. The survey reports considerable decline in number of Damselflies and Dragonflies. The flood has altered the microhabitat of Odonates; this is evident from streams and stagnant waterbodies. The population of Damselflies and Dragonflies have shown a drastic decline along streams as observed in the surveys conducted earlier. The study identifies a substantial decline in the population of many of the stream dwelling Damselfly species like Heliocypha bisignata, Libellago indica, Euphaea fraseri, Neurobasis chinensis, Copera marginipes, Copera vitata and Vestalis gracilis.
- The survey targeted analyzing the population and diversity of Lyriothemis acigastra During the survey, the species was spotted in Kattampally, Kannur which is a new record of the species from this place. The presence of this species in good number indicates that the flood has not impacted the population of the species. The results suggest that, after an initial drop in the population, the species have recovered
- Pantala flavescens the migratory Dragonfly has been sighted less in number compared to 2017 and 2018. The reduction in number can be attributed to delayed migration because of the extended rainy season. But the numbers have been gradually increasing as observed in the field work in October 2019. The survey has documented the flight of many of the indicator species and the abundance of

these species were considerably good to report that the Odonate population have recovered from the impact of the flood. The study further identifies that Odonates are the best among the indicator species studied. By monitoring these species, the health of the ecosystem they thrive in can be monitored on real-time basis.

- The current study recorded high numbers, both species and individual count, of invasive species in most of the habitats covered under the survey. Lantana camara, Mikania micrantha and Water hyacinth (Eichhornia crassipes) was sighted in large spreads in Kole and Vemband. Cabomba was seen spread over 3/4th of Pookode Lake. Giant salvinia (Salvinia molesta) was found in most of the wetlands in the current study.

Faunal diversity of Chalakudy River Basin

- 53 Species of mammals in 24 families and 9 orders have been reported from the Chalakudy river basin during the present study. Malabar Giant Squirrel was the most abundant animal at Chalakudy river basin, followed by Bonnet Macaque, Spotted Deer , while only three Wild Boar could be counted during the large mammal census.
- Chalakudy river basin record a total of 273 species of birds. This includes 11 species of birds that are endemic to Western Ghats. Two threatened (Vulnerable category, according to IUCN) species such as Nilgiri Wood-Pigeon and Woolly-necked Stork are also present at Chalakudy RB. It can be seen that post-flood scenario the number of species of birds have increased, by about 29 species while there is a substantial increase to the tune of up to three times in the number of individuals of birds

The bird diversity and abundance during pre and post flood at Chalakudy RB

- A total of 184 individual herpetofauna composing of 49 (16 species of reptiles and 33 species of amphibians) were detected during the visual encounter survey.
- Sixty-one species of fish belonging to 23 families occur in the Chalakudy River system, of which 17 species are listed as threatened on the IUCN Red List (two species CR. 11 species EN and 4 species VU). Thirty-eight species of fish found in the Chalakudy are endemic to the Western Ghats of which, 14 are endemic to the Kerala part of the Western Ghats, demonstrating the importance of the river system in the conservation of the endemic fishes of the Western Ghats. Many species of fish found in Chalakudy River show migration, either for fulfilling their feeding requirements or for the purpose of spawning. Major migratory species found in the Chalakudy basin include the Eels (Anguilla spp.) and the Mahseer (Tor spp.). Major threats to the migration of these species include the loss of critical habitats due to river engineering structures (dams, barrages, checkdams) as well as changes in morphology of the river basin.
- Among the invertebrates, the present study reported 37 species of butterflies in five families and 20 species of odonates (dragonflies and damselflies)

Table 10 ***Bird diversity and abundance during pre and post flood- Chalakudy river basin***

Flood	No. species Reported	No. individuals
Pre-flood	169	2916
Postflood	198	9102

5 IMPACT OF FLOODS ON SOIL BIOTA OF PAMBA, PERIYAR AND CHALAKUDY

PAMBA

Soil micro arthropods are sensitive as well as dependent on its ecological conditions, and respond to disturbance of soil structure, they could be good biological indicators of soil conditions. Soil arthropods are frequently used as ecological indicators to monitor environmental changes and ecosystem pressures. Flood affected areas of Pampa River basin from Ranni to Chengannur were studied for population density and diversity of major soil animal groups study area cover 3 Taluks: a. Ranni Taluk b. Kozhencherry Taluk c. Chengannur Taluk.

MAJOR FINDINGS

- From the soil physico-chemical parameter studies it was found that after flood all parameters decreased from their normal level, that also affect the population density of soil biota.
- From the population dynamics study it was found that before flood the soils showed more population density of most of the soil animal groups when compared to after flood soil. The highest population density during pre flood season was due to optimum soil pH, soil temperature, organic carbon content and adequate soil moisture.
- The post monsoon showers along with highest organic carbon content of soil following the monsoon weathering favours the density increase of soil biota's in post monsoon season. The principal component analysis result showed that pH, organic carbon, moisture and temperature, Nitrogen, Potassium, Calcium and Magnesium were the important factors controlling the distribution of soil arthropods.

Most Affected Species

Collembola: *Cryptopygus thermophilus, Alloscopus tetracantha, Cyphoderus javanus, Lepidocyrtus suborientalis*

Isopoda: *Philoscia javanensis, Philoscia indirae, Porcelloio scaber, Alloniscus pigmentatus, Philoscia muscorum, Porcellio laevis, Porcellio marcandicus.*

Pseudoscorpions: *Metawithius keralensis, Metawithius parvus, Metawithius nepalensis*

- Eleven groups of soil animals were recorded from the study sites during **pre flood** season. They were acari, diplopoda, isopoda, annelida, collembola, hymenoptera, isoptera, orthoptera, coleopteran, gastropoda and pauropoda. During post flood season isopoda, collembolan, isopteran, orthoptera, gastropoda, pauropoda and coleoptera were not at all represented in the sample in all sites. Here Acari, diplopoda and hymenoptera were least represented.
- From principal component analysis, it could be observed that temperature, pH , EA, EB, Moisture, Nitrogen, Potassium and Calcium were the primary principal factors affecting density of Isopoda, Annelida, Hymenoptera, Orthoptera, Gastropoda and Pauropoda during post monsoon inRanni area. Second principal factors affecting density of Collembola, Hymenoptera, isoptera and Coleoptera are found to be EA, EB, clay, moisture, Nitrogen, Phosphorus and potassium. Density of Diplopoda, Isoptera, Annelida, Collembola and Hymenoptera are found to be affected by a set of third principal factors such silt, clay, Magnesium and calcium

Table 11 Distribution of Selected microbial phyla in post flood and pre flood scenario.

Phylum	Relative Abundance (%)					
	MV (PRF)	MV (POF)	.PV	KD	KAL	KDL
Proteobacteria	65	58	19	67	67	66
Acidobacteria	2	0	0	1	1	4
Chlorobi	1	0	0	0	0	0

6 IMPACT OF LANDSLIDES AND FLOODS ON LIVELIHOOD OF TRIBAL COMMUNITIES IN FLOOD AFFECTED AREAS

6.1 VAZHACHAL, THRISSUR DIST

The study investigated various aspects of livelihood of tribal communities after flood. For the detailed investigation five tribal colonies viz., Vazhhachal, Poringalkuthu, Pokalapara, Mukkampuzha and Malakkappara where flood was affected widely were selected. The study area is located at 10.293301° North latitude and 76.565723° East longitude along Western Ghats, Thrissur district of Kerala which comes under Sholayar range of Vazhachal forest division under (36) km from Chalakkudy. The survey reveals that to ensure sustenance of populace in the study area, the intervention of the Government through suitable agencies like self-help groups or Vana Samrakshanan Samiti(VSS) is urgently required.

KEY FINDINGS

In the survey 101 ethno botanically important plant species belonging to 50 families, 3 fish species, honey and bees wax availability were studied. Most represented family of plant species studied was Dioscoreaceae. Second most represented families were Acanthaceae and Zingiberaceae. The third most represented families were Lamiaceae and Euphorbiaceae. After the floods and landslides a massive destruction of honey bee hives occurred in all tribal colonies studied.

Kadar Tribes

The Kadar tribes are a small group of ethnic community in Southern India residing in the hilly areas of Thrissur and Palakkad districts of Kerala. Kadar is one among the most primitive tribal groups in Kerala. More than half of Kadar tribes (58%) reside in the Thrissur district, with a population of 1082 persons, including 511 men and 571 women.

Details of Kadar in Thrissur district shows that 74.3% of the Kadar tribe lives in the Athirapilly Grama panchayat area, with a total of 237 families. 68 families inhabit the Mattathur Grama panchayat . There is only one family residing in Varantharapilly Grama panchayat.

Vazhachal Tribal Colony

Vazhachal Tribal colony is located near by the Vazhachal tourism area. They depend on forest for their livelihood by collecting minor forest produce. The items of NWFP collected from this area are Honey, white dammer, Maramanjal kol, Nellikka (gooseberry), Kasthuri manjal, Chandana kizhangu, Nannari, Beewax, Kudampuli, eeta, bamboo etc. The survey on ethnobotanical resources revealed decline of 35 items out of 106 resources surveyed in

Vazhachal colony and is estimated 33% of ethnobotanical resources were decreased in the study. As per the compiled data of respondents, 20 plant species and 12 NWFP and 3 fish resources are found to be decreased after the flood and landslides.

Pokalappara Tribal Colony

Most of the Kadar from the Pokalappara colony engages in fishing. The fish varieties they catch are *Pachilappodi, Kadla,Piloppy, Malingil* etc. They also depend on forest for NWFP collection. The main items of NWFP collected from this area are Honey, *Cheenikai, White dammer, Palmuthuk, Makkumkaya, Maramanjal kol, Kasthurimanjal, Chandana kizhhangu*, Beewax etc. The survey revealed, 18 plant species, 11 Non-Wood Forest Products (NWFP), 2 major fish resources were declined after the flood in Pokalapara colony which accounts for about 29% decline in the ethnobotanical resources. *Rotula aquatic*, a medicinal plant species locally called *'Kalloorvanchi'* faced severe destruction in their habit after flood; since they grow only between the rock beds of river . Major loss is observed in case of *Rotula aquatic, Garcinia gummi-gutta,* Blechnum species etc.

It shows 31 resources are drastically affected by flood, among these 11 species is used by tribal people for their own purpose such as medicinal use, as food, oil yielding etc. Forest products having high market value; like white dammer, black dammer, honey and bee wax, also declined after flood. 16 resources declined thus leading to decrease in both sale and own use status.

Among fish resources, *Devaria malabaricus*, *Labeo catla* are the major species declined in river. Heavy water flow possibly destroyed the eggs and washed away entire fish population.

Poringalkuthu Tribal Colony

Poringalkuthu colony is situated nearby the Poringalkuthu dam, nearly 13 KM from Athirapilly tourism spot. Their main income is from the minor forest produce and daily wage labour in the estates, plantations etc. The main items of NWFP collected from this area are honey, *Uruvanchi, Pathiri, white dammer, Maramanjal kol, Nellika, Kasthuri manjal, Cardamom, Chandana kizhangu, Nannari, Beewax* etc. They depend on the adjacent forests, river banks for NWFP collection. Both men and women are engaged in the collection of various minor forest resources like *Pathiri, Marottikuru, wild ginger, Kuuva* etc. Of the 106 ethnobotanical resources surveyed , 20 plant species, 8 NWFP and 3 fish species resource availability decreased drastically due to flood and landslides in the area; which accounts for about 29% decline in the ethnobotanical resources in Poringalkuthu tribal colony. Availability of common fishes like *Catla, Pachilavetti, Paral* drastically decreased after the flood.

Of the 31 ethnobotanical resources affected by the flood, 13 resources was used by Kadar tribes for their own purpose; 3 resources used for sale purpose only and the rest 15 resources had both utility.

Mukkampuzha Tribal Colony

Their main livelihood is from the forest produce collection and fishing from the reservoir. They are also engaged in honey and other NWFP collection on its season. They depend exclusively on fishing and NWFP collection. They have indigenous treatment methods for snake bites.

Watchumaram Tribal Colony

The main items of NWFP collected from this area are; Honey, *Vellari, Uruvanchi, Pathiri, whitedammer, Palmuthhuku, Makkumkaya, Maramanjal kol, Nellika, Kasthuri manjal, Cardamom, Chandana kizhanguu, Nannari, Beewax , Kudampuli* etc.

Sholayar Tribal Colony

The main livelihood of the people is NWFP collection. The main items of NWFP collected from this area are Honey, *Uruvanchi, Pathiri, whitedammer, Palmuthuku, Kakkumkaya, Maramanjal kol, Nellika, Kasthuri manjal, Cardamom, Chandana kizhanguu, Nannari, Beewax, Patripoo, Thelli, manjakoova, Turmeric, Maravettikkuru*, wildpepper etc. They are also engaged in pepper and cardamom cultivation in the colony.

Malakkappara (Peruumpara) Colony

The main items of NWFP collected from this area are Honey, vellari, Uruvanchi, Pathiri, whitedammer, Palmuthhuku, Makkumkaya, Maramanjal kol, Nellika, Kasthuri manjal, Cardamom, Chandana kizhanguu, Nannari, Beewax , and Kudampuli. They are also engaged in fishing, Kadla, Choora, Pachilotti, Eettavetti and Kooran are the fish varieties. They collect Honey, Pathirippo, (Jathipathri),Pulinjikkaya and Thelli. Of the 106 ethnobotanical resources surveyed, availability of 22 resources was decreased after flood and landslide, which accounts for about 21% decline in the ethnobotanical resources. Tribal people in this colony routinely collect non wood forest products like honey, dammer and bee wax which are now declined tremendously.

- The survey revealed that massive flood and land slide in the area caused significant decline in various forest resources including ethnobotanical resources. About 77 plants with ethno botanical uses was recorded.
- In Vazhachal colony 33% decrease of NWFP was recorded. Whereas in Malakapara colony decrease in NWFP was 21%. In Pokalapara and Poringalkuthu 29% decrease in ethnobotanical resource was noticed. In Mukkapuzha decrease was 24%.
- As the NWFP resources are decreased significantly, % decrease in income from NWFP was also noticed. During the survey, it has been revealed that in Vazhachal colony, 25%, in Pokalapara and Poringalkuthu 23%, and in Malakapara 17% decrease in income from NWFP was recorded.
- Survey on agrobiodiversity loss due to flood and landslide, it has been revealed that mild loss only occurred due to flood. The loss was mainly noticed near river banks where many of the trees such as *Garcinia gummi-gutta*, *Depterocarpus* sp. are uprooted due to heavy water current and removed. Regarding the crop plants maintained by the tribal people in the colony, it seems that most of the perennials such as Coconut, Clove, Papaya, banana survived havoc of food.
- As per the response major loss due to flood was the fish resources in the Dam and river. Fishing is an important livelihood of the tribal community in the area. The survey roughly estimates that compared to previous year in the same season this year fish catch was 44% less in Poringalkuthu that in turn significantly decreased income in this colony.

- The flood also affected various wild fruits and vegetables, including leafy vegetables in all the five colonies studied. In Pokalapara colony 30% of fruits and vegetables decrease was recorded. Apart from damage due to flood, high frost condition followed by severe dry season during the surveying period (January-April) caused severe decline in fruits and vegetable resources.
- The survey conducted in flood affected Vazhachal forest division showed about 27% mean ethnobotanical resource loss. The decrease was high in Vazhachal tribal colony (33%) this loss in NWFP caused about 22% mean decline in income of the people.
- During the survey it is noticed that income to tribal persons decreased significantly due to the after effect of flood. The scenario had made a difficult situation to local people. NTFP resource crunch and consequent crisis is therefore need to be addressed effectively. In this regard agencies like *Vana Samrakshana Samiti* (VSS) like agencies can effectively contribute by initiating steps to promoting bee keeping in the area, vegetables and spices cultivation, fish farming etc. such activities will support livelihood of the people in the area. The activities of tribal welfare society and self-help groups such as kudumbasree and purusha swayam sahaya sangam are to be rejuvenated further especially for confidence building to initiate small scale vegetable cultivation, bee keeping etc. In Malakapara colony respondents informed that the functioning of Malakkapara Tribal Society was stopped for a long period. The society was highly supportive to get better price and timely release of price to the gather products. After closure of the society the NTFP dwellers faces problem in selling their collected NTFPs. Therefore it is recommended that active support from various developmental society it to be insured for collection and selling the gathered NTFPs in the entire study area. Also special attention is needed in the case of Malakkapara where marketing the product directly by the collectors are extremely difficult as the place is quite far away from the village and panchayat headquarters. After flood frequency of wild animal conflict is increased possibly due to disturbance and habitat loss of the animals or scarcity of food in their natural habitats. Therefore effective measures to keep away wild animals from the settlements are to be initiated. Electric fencing available in some settlements are partially damaged after flood, and needs to be made functional at the earliest.
- To take up the land slide and other calamities in future, it is recommended to provide training in disaster management to the people in this area. Promoting native fruit plants in the buffer areas of wild life sanctuaries is also recommended to reduce invasion of wildlife especially monkeys in the colonies.

Table 12 List of resources declined due to flood- Vazhachal

Sl. No.	I Plants
1	*Achyranthes aspera L.*
2	*Bacopa monnieri (L.)Pennell*
3	*Blechnum sps*
4	*Boerhavia diffusa L.*
5	*Centella asiatica L.*
6	*Colocasia esculenta L.*
7	*Cynodondactylon (L.)Pers.*
8	*Dioscorea alata L.*

Sl. No.	I Plants
9	*Ecliptapro strata L.*
10	*Entada rheedeiS preng.*
11	*Hemidesmus indicus (L.) R.Br.*
12	*Ichnocarpus frutescens (L.)R.Br.*
13	*Leucas aspera (Willd.) Linn.*
14	*Piper barberi Gamble*
15	*Pittosporum neelgherrense Wight &Arn.*

16	*Rotula aquatica Lour.*
17	*Sida acuta Burm. f.*
18	*Sida rhombifolia L.*
19	*Terminalia paniculata Roth.*
20	*Zornia gibbosa Span.*
21	*Emilia sonchifolia (L.) DC.*
22	*Hemigraphis colorata (Brumf.)T.Anderson*
23	*Phyllanthus amarusS chum. &Thonn.*
24	*Physalis peruviana L.*
25	*Scopari adulcis L.*
26	*Uvaria narum (Dunal) Wall.*
27	*Eusteralis quadrifolia (Benth.)F.Muell.*
28	*Hemigraphis alternata (Burm. f.) T. Anderson*
29	*Zehneria maysorensis Arn.*
30	*Cyclea peltata (Lam.) Hook. F. & Thomson*
31	*Strobilanthes heyneanus*
32	*Zehneria maysorensis (Wight &Arn.). Var. maysorensis*
	II. NWFP
33	*Bambusa bambos (L.) Voss*
34	*Canarium strictumRoxb.*
35	*Curcuma neilgherrensis Wight.*
36	*Curcuma zedoariaRosc.*
37	*Elettaria cardamomum (L.) Maton*
38	*Garcinia gummi-gutta (L.) Robs.*
39	*Honey*
40	*Myristica malabarica Lam.*
41	*Ochlandra travancorica (Bedd.) Benth.ex Gamble*
42	*Piper longum L.*
43	*Piper nigrum L.*
44	*Vateria indica L.*
45	*Vetiveri azizanioides (L.) Nash.*
46	*Bee wax*
47	*Coscinium fenestratum (Goetgh.) Colebr.*
48	*Phyllanthus emblica L.*
	III. Fishes
49	*Devaria malabaricus*
50	*Labeo catla*
51	*Oerochromis mossaloicus*
52	*Hypselobarbus carnaticus*

Table 13 Ethnobotanical resources - Vazhachal

SL.No.	Uses/remedies	Total no. of plant species
I. Plants		
1	Folk medicine	1
2	Headache	5
3	Body stimulant and for lactation	1
4	cure scabies	1
5	Ulcer	1
6	knee pain	1
7	Jaundice and Anemia	2
8	Blood purification	2
9	Toothache	2
10	Stomach ache	6
11	Inflammation	2
12	Tonsillitis, cough	6
13	Small pox	1
14	Leprosy	2
15	Asthma	2
16	kidney stone	2
17	Snake venom	4
18	fever and cough	7
II. NWFP Items		
19	Chronic rheumatism	1
20	Leprosy and skin diseases	2
21	Urinary complaints	1
22	Improving digestion	2

6.2 Attapady

The traditional cultivation area used by the Muduga community of Karuvara farm region is called *Panjakkadu*. The floods had mainly affected the *Panjakkadu* region due to landslides that happened in sloppy areas. The associated biodiversity destruction mainly occurred in the 6th block of Karuvara*ooru* region. Chindakki region faced destruction of forest area cultivation land caused by the movement of rocks and tree debris through the

check dam premises. Malleeswara peak is the highest peak in the Attappady forest reserve, holding great significance to the tribal cultural beliefs and myths. Tribal settlements near Malleeswara peak are Meleabbannoor, Thazheabbannor, Veettiyoor, Aanakkallu and Chottalkkulam. Chottalakkulam tribal settlement near to Aanakkallu faced landslides which affected the agricultural assets of the tribal colony.

It is noteworthy that the landslides that happened in the agricultural plots held by the settler farmers were concentrated in plantations and were more severe when compared to those that happened in traditional agricultural plots. Soil piping was observed at places where intensive plantation of cash crops such as areca nut was undertaken, primarily by the settler farmers. About 13 tuber crops and 15 leafy vegetables were collected. Many of the tubers have a bitter taste and tribals used to employ indegeneous processing techniques to remove the bitterness. There was a old custom called *Veettusappad* among the tribes in which if a family in the hamlet had gathered tubers, they would share it with the neighbours. They would not store the tubers for more than two days. The tubers are mostly considered as reserves for times of food scarcity. They are collected while the land is being prepared for cultivation after the harvest festival of Vishu, mainly during the months from May to July. Most of them are rooted deep in the soil. Tribal farmers reported these tubers as more climate resilient than the other staple food crops being grown presently. Because of the 2018 floods and the unusual drought that followed, recovery of tubers was reported to be much difficult. Adiyakandiyur, Chindakki, and Seenkara hamlets reported large scale loss of tubers during the flood. Many of the wild edible crops are identified as weeds by the single crop farming system introduced by the settlers, which is the mainstream agricultural model at present.

Table 14 Edible Tubers - Attapady

No	Vernacular Name	Botanical name	Family	Habit
1	*Kattukuvakkizhangu*	*Curcuma angustifolia*	Zingiberaceae	Herb
2	*Sathavari*	*Asparagusofficinalis*	Asparagaceae	Climber
3	*CheruKizhagu*	*Dioscoriaesculenta*	Dioscoreaceae	Climber
4	*Kachil*	*Dioscoriaalata*	Dioscoreaceae	Climber
5	*Madhurakizhangu (Vellakash)*	*Ipomeabatatus*	Convolvula-ceae	Vine
6	*Katunurenkelangu*	*Dioscoreapentaphylla*	Dioscoreaceae	Climber
7	*Kattukachil (Air potato)*	*Dioscoreabulbifera*	Dioscoreaceae	Climber
8	*Chavalkizhangu*	*Dioscoreahispida*	Dioscoreaceae	Tuberous herb
9	*Nillapana*	*Curculigoorchioides*	Hypoxidaceae	Herb
10	*Kattuchembu*	*Colocasiaesculenta*	Araceae	Tuberous herb
11	*Vellakkuva*	*Curcumaneilgherrensis*	Zingiberaceae	Herb
12	*Anakuva*	*Cheilocostusspeciosus*	Costaceae	Herb
13	*Marnnukachil*	*Dioscoreafloribunda*	Dioscoreaceae	Climber
14	*Kavalakivzhzngu*	*Dioscoreaspicata*	Dioscoreaceae	Twiner

Table 15 Edible leafy vegetables - Attapady

Sl No	Vernacular Name	Botanical name	Family	Habit
1	*Kozhuppacheera*	*Portulacaoleracea*	Portulacaceae	Herb
2	*Ponnamkannicheera*	*Alternantherasessilis*	Amaranthaceae	Postrate herb
3	*Mullancheera*	*Amaranthusspinosus*	Amaranthaceae	Sub shrub
4	*Thazhuthama*	*Boerhaaviadiffusa*	Nyctaginaceae	Herb
5	*Thakara*	*Cassiaobtusifolia*	Fabaceae	Shrub
6	*Pokkanamthooki/Uzhinja*	*Cardiospermumhelicacabum*	Sapindaceae	Climber
7	*Thavalapottan*	*Commelinabenghalensis*	Commelinaceae	Herb
8	*Kuppacheera*	*Pouzolziazeylanica*	Urticaceae	Herb
9	*Mallicheera*	*Erynjiumfoetidum*	Apiaceae	Herb
10	*Kadithuva*	*Trajiainvolucrata*	Euphorbiaceae	Herb
11	*Moshamoshakka*	*Mukiamaderapantana*	Cucurbitaceaea	Runner
12	*Churulai*	*Diplaziumesculentum*	Athyriaceae	Herb
13	*Munnadaag*	*Premnacorymbosa*	Verbenaceae	Shrub

- Some non-conventional food crops are nutritionally at par or superior to conventional food plants.
- Many of them are adaptive and tolerant to adverse weather conditions and have inherent resistance to diseases and pest,
- They represent valuable gene pool for genes conferring resistance to disease, pest, biotic stress and genes for better nutritional quality.
- Many of them grow well in nutrient poor marginal land not suitable for major crops.
- It was revealed that the traditional potentially climate-resilient crops of tribals, constituting leafy vegetables and tubers among others, have not been documented, and neither are their nutritional properties studied. Initiatives have to be taken up for documentation and nutritional studies of such crops.
- The study suggests that apart from interventions like the community kitchen programme, which provides cooked food to tribal families, Support to the processing, value addition, and marketing of traditional crops is a needed step.

7 IMPACT OF FLOODS ON AGRICULTURE- ALAPUZHA (KUTTANAD) AND WAYAND

7.1 KUTTANAD- GLOBALLY IMPORTANT AGRICULTURAL HERITAGE SYSTEM

Kuttanad the rice bowl of Kerala is the only area in India where rice is cultivated below the sea level and has been declared as Globally Important Agricultural Heritage System by FAO. The region is rich in Agrobiodiversity and fisheries wealth with 65 species of fin fish and 14 species of shell fish from the Vembanad region. Giant freshwater prawn (*Macrobrachium rosenbergii*), which grows up to the size of 40 cm and locally known as Kuttanadan konchu is a highly valuable species of Vembanad lake. It is estimated that more than one third of the water spread area in this wetland has been lost due to land reclamation and the expanse of the Vembanadlake is reduced by two thirds. Further the depth of the lake is also substantially reduced due to deposition of silt and sediments so that various ecosystem services has been threatened.

For improving agricultural production below sea level, and as part of effort to increase cropping intensity, for conversion of single crop paddy field in to double crop system, two important engineering interventions were taken up in Kuttanad, the one started during 1951 is Thottappally spillways and another in 1955, is the Thaneermukkom Barrage (TMB). This has been triggered largely by changes in the natural hydrological processes and sanity regimes in the estuary. An important outcome has been the total elimination of tidal flushing which has exponentially enhanced pollution levels in Kuttanad. The most serious repercussion has been the rapid decline of estuarine fish production and the livelihoods of the dependent people, consequent to changes of the estuarine system into a totally fresh water ecosystem. Consequent to the utilization of the below sea level paddy fields for rainy season cropping, popularly called 'additional crop' without allowing flood water entry to the vast stretch of polder system, flood fury got augmented. This was largely because the large quantum of water that enter the Kuttanad flood-plains has to flow to the open Vembanad lake through myriad of narrow meandering canals between the pasasekharams. These canal systems, about 1500 km were heavily silted up with blockages and exposed to encroachment, which also impeded drainage.

The catch of the endemic prawn Macrobrachiumrosenbergiiof lakeVembanad which was (429 t) in 1960, has come down to 26.72 t during 2000-2001 and to 57.69 tons in 2014. The salinity barrier was responsible for the alarming depletion of M.rosenbergii. Some of the

commercially important fishes like milkfish, Chanoschanos, marine catfish, (Tachysurus) pearlspots, (Eroplussuratensis) giant fresh water prawns (Macrobrachiumrosenbergii) have either vanished or become rarity. This has been attributed to changes in the prevailing water regimes, in the wetlands caused by change in salinity regimes and disruption in the physical and biological continuity of the lake with the coastal waters. The wetland have also been an important habitat for a rich varieties of birds, including several migratory species. The avian population have declined sharply by more than 40% since early 1990's. Widespread use of improved rice varieties in Kuttanad since late 1960s with the advent of Green revolution and the new plant types, despite high yield have also prompted the substitution of traditional germplasm with the uniform varieties with narrow genetic base. It is supposed that about two thousand traditional varieties of rice, which were well suited for different agro ecological situations that prevailed in Kuttanad in the past, have vanished. The present study covered the upstream reaches of Vembanad wetlands covering the Kuttanad agro ecosystem, extending from Vaikom on the north to Ihrikkunnapuzha on the south. The study highlights the need for nonstructural alternatives, for flood management by integration of the natural dynamics of flooding, restoration of wetland areas and reconnection of key floodplain areas.

MAJOR FINDINGS

- The study points out an increasing trend in salinity, year after year in the Vembanad lake and Kuttanad region during post monsoon months, partly due to the environmental effects of the hydrological modifications at Cochin bar mouth as part of the Vallarpadam Container Terminal Project, and poor inflow from river systems during post monsoon months-probably induced by climate variability. Long period of inundation in Kuttanad with flood water not receding fast points to the failure of the spillways system constructed exclusively for flood control.
- The study indicates that the area under varshakrishi in Alapuzha and Kottayam is increasing lately and over 45 % of the land area under rice is put to use for varshakrishi in Kuttanad. Although it is recommended to limit the varshakrushi to not more than 30% this is not generally followed reducing the space of flood waters and augmenting the severity of floods. Flood cushioning in Kuttanad paddy fields are different from paddy fields in valley bottom paddy lands in midlands of Kerala in valley bottom paddy lands reduction is paddy field area increase flood hazards where as in Kuttanad increase in area under rainy season rice farming enhance floods. Hence increase in varshakrushi shall not increase beyond 30% shall not be promoted as Kuttanad polders are different from paddy fields in other areas, owing to its unique role of flood cushioning.
- The major impact on environment in all stations was an increase in salinity during post monsoon and premonsoon. Salinity recorded highest value of 16.8ppt at Thrikkunnappuzha on the south during February 2019. The highest value of 4.3ppt was reported during March 2019 at Thanneermukkom south of the barrage although the barrage was closed indicating rapid incursion of saline waters into Kuttanad region consequent to decline of water levels after the devastating deluge. Maximum salinity variations were observed in Vaikom North of Thanneermukkom barrage.
  The incursion of saline water to upstream regions of Thanneermukkom barrage during 2018 prior to the flood indicate that despite closure of the barrage saline incursion beyond permissible levels can only be attributed to extreme reduction of water level. The situation calls for efforts for maintaining a minimum seaward

environmental flow in the wetland by storage of water in the flood plains. The suggestion to utilize the uncultivated Padasekharam in Kuttanad seasonally as water storage structures during rainy season assumes relevance in the context of climate change related water stress.

- According to CGIAR report the extend and intensity of salinity in the coming years are likely to increase due to climate change induced salt water intrusion a clear indication of the distressing trend of saline incursion in coastal wetlands.The study indicates that although the barrage was closed at Thaneermukkam south of the barrage salinity increased indicating rapid incursion of saline water into Kuttanad regions consequent to decline of water levels after the floods. This situation calls for maintaining a minimum seaward environmental flow in the wetland by storage of water in the flood plains. The suggestion to utilize uncultivated Padasekarams in Kuttanad seasonally as water storage structures during rainy season assumes relevance.
- Dissolved oxygen in surface water during the post flood period ranged from 0.8 to 7mg/l with an average of 3.2 mg/l. the observed low value was significantly lower than the desired level of DO for sustenance of aquatic organisms. The dissolved oxygen in Thrikkunnapuzha the flood water discharge point close to Kayamkulam estuary reached almost 0.8 mg/l, a near hypoxia situation immediately after flood during October 2019. Oxygen levels below 1-2 mg/l even for a few hours can result in fish kills. A similar decline to drastically lower level up to 1.2 mg/l and 1.3 mg/l was observed at Vaikom, and Thottappally sector respectively, both locations representing the exit points for flood waters. This could only be attributed to the high organic loading consequent to flood and deluge. Dissolved oxygen is a critical parameter in aquatic ecosystems and one of the important chemical parameter for water quality. The optimum value of DO for survival of aquatic life is known to be 4-6 mg/l. Oxygen levels below 1-2 mg/L even for a few hours can result in fish kills. The depressing concentration of DO is a negative effect of the flood event, linked to breakdown of organic matter.This indicates that structural engineering mechanisms such as spillways and ring bunds around polders or barrage constructed to master nature by altering hydrologic regimes cannot be a solutions but, such civil structures only create hurdles to smooth flow.
- Pelagic fishes that lay their eggs in the inundated paddy fields in the cold floodwaters were benefitted. Large schools of fishes were found abounding the polders during and after the flood, this highlight the role of flooded padasekharams as natural fish nurseries. This points to the dire need for utilizing the polders seasonally as flood water storage systems, and fish reproduction protection zones for endemic fishes and water harvesting structures that enable post monsoon seaward flow to hold up salinity ingression.
- The physical obstruction of barrage has led to alteration of upstream and down stream migration of giant river pawn and prawns with poor swimming ability was washed downstream locations in flash floods.
- Nitrates and phosphates are known as critical plant nutrients. In open Vembanad lake the its concentrating has been exhibiting abnormal trends during different years. Abnormal concentration of nutrients in Kuttanad waters can only be attributed to incessant human interventions and organic enrichment through diverse infringements in the ecosystems.
- *Total Organic Carbon:* Studies in kuttanad revealed that the wetlands receive 1 to 26 tons of organic matter annually and the present study indicated that after the

deluge quantum of silt and sediments deposited in riparian zone of river Pampa near Mannar was as high as over 130 tons/ha.

- *Phytoplankton:* The highest incidence phytoplanktons were observed in open lake waters in Kumarakom and riverine station and at the riverine stations in Muttar region of the Manimalariver. Phytoplanktons are the major producers in the aquatic ecosystems; their role in the food chain is of paramount importance. Despite high nutrient availability, algal abundance was reduced and primary production also suffered initially because waters were more turbid, light was a serious limiting factor and flushing rates apparently exceeded algal growth rates. As transparency increased after a few months, algal growth was stimulated. Primary production was enhanced subsequently in latter months. The increase in primary production is attributed to increased phosphorus (P) and nitrogen (N) loading was facilitated by floods.
- During the flood, paddy fields were also teeming with exotic escapee fishes from aquaculture farms like Oreochromis, Pangassius, Piaractus sp. etc. Spread of such exotics has been a serious threat to endemic ichthyofauna. This highlights the dire need for effective measures for prevention of unlawful introductions, fish keeping and breeding of such alien fish species in natural river systems with utter disregard to biosecurity shall be forbidden calls for invoking legal provisions against the offenders.
- Even after 6 months, large number of fishes that have escaped have intruded in the ponds and water bodies and are caught in normal catches. Small and large specimens of ornamentl fish like gouramis, sucker fishes that escaped from aquarium centres were also spotted, maximum number of food fishes, *Pangasianodon hypophthalmus*and Tilapias were encountered at flood exit points in Thottappally spillway at Alappuzha during the deluge days and later from almost all inundated padasekharams in Kuttanad, *Piaractus brachypomus* and later from almost all inundated padasekharams in Kuttanad, *Piaractus brachypomus* and *Oreochromis niloticus* were caught in considerable numbers duriong dewatering of the polders for annual punja rice farming. Atleast over 100 fishers were continuously engaged in fishing for such escapee fishes using diverse gears, almost round the clock for over 25-30 days during the flood period. Alien species exotic to the lake encountered during the study were *Poecilia reticulat*e (rainbow fish), *Oreochromis mosambicus* (mozhambique tilapia), *Oreochromis niloticus* (nile tilapia), *Ptergoplichthys* (Janitor fish), *Clarias gariepinus* (African sharptooth catfish), *Xiphophorus hellerii* (Green swordtail), *X.maculates* (Moonfish), *Piaractus brachypomus* (pacu/piranha) *Pangasiannodon hypophthalmus* (Iridescent shark/shark catfish), *Osphronemus goramy* (Giant gourami), *Piaractus brachypomus* (Red-Bellied Pacu), *Pterygoplichthys multiradiatus* (sailfin catfish), *Poecilia reticulata* (guppy), *Pterygoplichthys pardalis* (amazon sailfin catfish), *Pygocentrus nattereri* (red bellied piranha), *Clarias gariepinus*(African catfish), *Helostoma temminkii* (kissing gourami), *Trichopodus leerii* (Pearl gourami), *Trichopodus trichopterus* (Opaline gourami).
- *Flood Impact on endemic prawn* **(***Macrobrachium rosenbergii***):** The upstream and downstream migration of the giant river prawn, *Macrobrachiumrosenbergii*, (KuttanadanKonchu) was totally disrupted due to ecosystem alteration.
- *Black Clam Villorita cyrpinoides landings:* A comparison with earlier reports showed that the live clam resources of the lake exhibit a diminishing trend over the years.
- *Land use changes and Flood:* The probable effect of land use in Kuttanad on flood incidence was investigated. The study reveals that the land area under varshakrishi in Alappuzha &Kottayam has been on the increase lately. The area under varshakrishi

in Alappuzha was 8237ha during 2013 and this had increased to 13225ha during 2017. In Kottayam the area under varshakrishi was 5306ha during 2012. This had increased to 9809ha during 2017. This indicate that over 45% of the land area under rice is put to use for Varshakrishi lately in Kuttanad.

- Species that are dependent on bottom substratum for feeding and breeding behaved differently than seasonal breeders. The cleansing effects of the flood flows in post flood months provided them high transperancy, this is evident from the high yield of Karimeen, in latter months.
- Extreme organic loading consequent to floods and prolonged water logging apparently led to anoxic conditions in water which has been critical to all life forms. But this helped mobilization of more P within the system by 'internal eutrophication' due to release of P from sediments. Long term inundation apparently favored release of P bound in sediments.
- The stable water quality conditions and the less turbid waters after initial pulse of flood favored the profuse growth of filamentous algae. This also in effect benefitted the endemic fish Karimeen, the algal browser Etroplussuratensis and the known filter feeder, Villoritacyprinoides both commercially important to the livelihoods of the 'ecosystem people' the fishers.
- Floods have increased the fish diversity partly due to more diverse habitats becoming available to fishes. Flooding improved agricultural soils by depositing sediments on floodplains, helped recharge farmlands soils and significantly increased suitability of soils for farming and increased productivity of rice is a testimony to this. This is facilitated in part by enhanced nutrient availability.
- Floods improved soil condition due to long inundation, helped washing of acidity and removal of residual salts like sodium from soils. Flooding improved soil formation by depositing sediment on flood planes. Increased deposition of particulate organic carbon in soil after a flood underlines indicated the role of wetlands behaving as carbon sink, a very significant role in the context of climate change.

8 FLOOD AND SPREAD OF INVASIVE SPECIES

8.1 INVASIVE ALIEN SPECIES OF FISH

Only 92 species of ornamental fish are legally allowed to be imported to India, of which 79 are of freshwater origin (Government of India http://aqcsindia.gov.in/pdf/trade-14.pdf). Three species of exotic fishes like *Oreochromis mossambicus*, *Cyprinus carpio*, and *Poecilia* sp. were present in Bharatapuzha. Tilapia and carp are stocked in large quantities in the Malampuzha reservoir which may escape downstream. Of the seven species that were recorded for the first time from the WG subsequent to the floods, many are illegally introduced and farmed for the aquarium pet trade, as they are not listed in the species allowed to be imported to the country. These included large-bodied and high-risk species such as the Arapaima (*Arapaima gigas*) and Alligator gar (*Atractosteus spatula*), top predators capable of feeding on a range of organisms and a serious threat to the endemic fish diversity of the WG region. Most breeding and farming units for aquarium fish in the WG region have no biosecurity systems, and function along the floodplains of major rivers that are vulnerable to annual flooding events.Two most important species that were recorded for the first time from the natural waters of Kerala were the Arapaima, Arapaima gigas and Alligator gar,. Arapaima, endemic to the Amazon is one of the 'mega fishes' of the world, growing up to 4.5 meters in length and 200kg in body weight, while the alligator gar native to the United States of America and Mexico, reaches body length and weight up to 3 meter and 137kg. Alligator gar are also known to feed on a range of organisms including fish, crustaceans, reptiles as well as aquatic birds and mammals threatening the very existence of freshwater-dependent biodiversity in regions where they are released (or escape into).

Chalakudy River

Several species of exotic/alien fish have been introduced into the country and at least twenty-four of them are now found to be widely distributed in the Chalakudy. These include Tilapias, Common Carp, African Catfish, Pacu, Grass Carp, Amazonian Sucker Catfish, Silver Carp, species of south American cichlids, as well as emerging species such as the Arowana and Arapaima. The main source of alien species in the Chalakudy River includes the innumerable aquaculture farms and ornamental fish hatcheries, farms and breeding units located on the banks of the river, as well as local aquarium stores. Yet another source of alien species is the amusement parks located on the banks of the river, which have many alien fish species in their garden ponds.

8.2 INVASIVE ALIEN PLANT SPECIES - ALAPUZHA AND WAYANAD

- A total of 134 invasive plant species were identified and documented from 17 villages of Karthikappally Taluk, Alapuzha. Of these 27 plant species (Terrestrial and Wetland) were found to totally invade the whole agricultural fields replacing the crops while others showed only partial invasion. In land system 17 invasive plants showed heavy invasion in agriculture fields. In terrestrial ecosystem the dominant plant species namely *Mikania micrantha, Merremia hederacea, Hyptis capitata, Calopogonium mucunoides and Pennisettum pedicellatum* totally covered the entire fields and compete with native plants for nutrients and minerals The invasion of these plants totally changed the crop rotation status and also affected the production strategies of the crops.
- On the basis of risk management, they were categorized as high risk, moderate risk and low risk category. In terrestrial habitat 115 invasive plant species were identified, from which 35 invasive plants are high risk types followed by 37 moderate and 43 low risk types. Out of the 19 invasive plants identified from the wetlands, 14are high risk type and the rest (5) moderate type.
- The detailed survey in the 17 villages revealed that effect of flood also acclerated the growth of the invasive plant species. Flood impact revealed that highest number of invasive spp.were identified in the highly flood affected region i.e, in Pathiyoor village and lowest in the least flood affected region i.e, in Keerikkad, Kumarapuram and Puthuppally villages
- Familywise analysis of invasive plants showed dominance of Poaceae (16 plants) followed by Fabaceae (13), Asteraceae (13), Amaranthaceae (9), Convolvulaceae (9), Euphorbiaceae (6), Salviniaceae, Cleomaceae and onagraceae (2 each). The flood drastically influenced the growth of Poaceae and Cyperaceae members. Several members of this plant family showed invasive nature and disturbed the growth as well as propagation of native plants.

Table 16 Alien species recorded from the natural waters of Kerala after the floods

Species	Common Name	Native Region
Piaractus brachypomus	Pacu	South America
Arapaima gigas	Arapaima	South America
Atractosteus spatula	Alligator gar	Central and North America
Oreochromis niloticus	Nile Tilapia	North Africa
Oreochromis mossambicus	Mozambique Tilapia	Africa
Pangasius hypopthalmus	Pangas/Basa	South East Asia
Pangasius sp	Pangasius	South East Asia
Osphronemus goramy	Gourami	South East Asia
Oreochromissp.	GIFT Tilapia	
Ctenopharyngodon idella	Grass Carp	China
Cyprinus carpio	Common Carp	Europe

- The wetland invasive plants under study were of submerged, free-floating or emergent types. Around 50% were emergent types followed by 39% free-floating and 11% submerged . In wetland ecosystem 10 invasive plant species dominated the agriculture fields of the 17 villages in Karthikappally Taluk. The presence of *Eichhornia crassipes, Pistia stratiotes, Azolla pinnata and Salvinia molesta* plants totally covered the entire wetland system and reduced the oxygen demands which adversely affected the life of aquatic animals.
- The effects of flood shifted the surface soils from one place to another helping easy propagation and growth of the invasive plants. The flood effects lead to eutrophication process which also leads the invasive plants abnormal growth.

Table 17 Alien species occurring in Chalakudy River

Sl. No	Common Name	Scientific Name	Type
1	Mozambique Tilapia	*Oreochromis mossambicus*	Alien
2	Nile Tilapia	*Oreochromis niloticus*	Alien
3	GIFT Tilapia	*Gift tilapia*	Alien
4	Giant Gouramy	*Osphronemus goramy*	Alien
5	Giant Gouramy	*Osphronemus goramy (Albino form)*	Alien
6	Sword Tail	*Xiphophorus helleri*	Alien
7	Platy	*Xiphophorus maculatus*	Alien
8	Mosquito Fish	*Gambusia affinis*	Alien
9	Rohu	*Labeo rohita*	Transplanted
10	Amazonian Sucker Catfish	*Pterygoplichthys sp (Red Colour)*	Alien
11	Amazonian Sucker Catfish	*Pterygoplichthys sp (Black Colour)*	Alien
12	Mrigal	*Cirrhinus mrigala*	Transplanted
13	Catla	*Catla catla*	Transplanted
14	Pangas	*Pangasius sp*	Alien
15	African catfish	*Clarias gariepinus*	Alien
16	Common Carp	*Cyprinus carpio*	Alien
17	Guppy	*Poecilia reticulata*	Alien
18	Silver Carp	*Hypophthalmichthys molitrix*	Alien
19	Pacu	*Piractus brachypomus*	Alien
20	Grass Carp	*Ctenopharyngodon idella*	Alien
21	Arapaima	*Arapaima gigas*	Alien
22	Kissing Gourami	*Helostoma temminckii*	Alien
23	Pacu	*Piaractus mesopotamicus*	Alien
24	Blue Gourami	*Trichopodus trichopterus*	Alien

Invasive species- Bharatapuzha, Pamba, Periyar, Chalakudy Riparain vegetation

- One of major impact of the August 2018 flood/landslide in Kerala to the riparian ecosystem/vegetation is the spread of many invasive plants.
- Initially there was a positive sign of washing out many such species from the banks but in a later stage it is found that all these plants are growing profusely in many other areas, especially in the mud/sand deposited areas.
- The present study has identified 48 out of the 82 plants as invasive species of Kerala from the riparian areas of four Rivers. The High Risk (A Category) consists of 13 (20 species listed from all over Kerala), Medium Risk (B Category) with 14 (22 species listed from all over Kerala), Low Risk (C Category) with 13 (14 species listed from all over Kerala) and Insignificant (D Category) with 13 (26 species listed from all over Kerala).
- River wise analysis has shown that Bharathapuzha is highly affected with 37 species (11 species under A category, 9 species under B category, 6 species under C category and 11 species under A category); followed by Periyar with 34 species (9 species under A category, 12 species under B category, 6 species under C category and 7 species under A category); Pampayar with 29 invasive species (10 species under A category, 8 species under B category, 6 species under C category and 5 species under A category) and Chalakudiyar is with 25 species (10 species under A category, 6 species under B category, 3 species under C category and 6 species under A category).
- It is also noticed during the study that all these invasive species are spreading to more areas of all the River side mostly in the newly deposited areas and this require special attention in the future action plan for conservation of riparian biodiversity.

Impact of plant invasiveness in agricultural fields of Karthikappally Taluk

The impact of invasive plant species in the flood affected areas of Karthikapally Taluk observed during the study are the following

- Heavy surface soil erosion
- Loss of Earthworms in the soil
- Total destruction of crop plants likeTapioca, plantains and pepper
- Invasion of species like *Eichornia, Salvinia, Azolla* and *Pstia* in paddy fields
- Deposition of Alluvial soil and clay in the agricultural field helping the easy growth and propagation of invasive plants
- Reduction in crop yield by competing for water, light, soil nutrients, space and crop quality
- These noxious weeds were found to limit the choice of crop rotation sequences and cultural practices in several fields.
- In Kandallor and Karuvatta regions most of the agricultural fields were partially covered with the invasive species like *Eichornia* and *Persicaria barbata* which hindered the cultivation as well as field activity.
- Changed the soil fertility and made the soil more acidic
- Competition with native plant species reduced native plant populations
- The effects of invasion led to eutrophication process in wetland system
- In Karuvatta village low land area, the farmers got beneficial effects due to deposition
- of fertile soil from other highland areas. They got double the yield of rice than the previous years

Table 18 Invasive Species - Wayanad				
Sl. No.	**Species**	**Family**	**Habit**	**Distribution**
1	*Acalypha indicaL.*	Euphorbiaceae	Herb	Indo-MalesiaandTropical Africa
2	*Ageratina adenophora (Spreng.) King & Robins.*	Asteraceae	Herb	South America
3	*Ageratum conyzoides L.*	Asteraceae	Herb	Pantropical
4	*Ageratum houstonianum Mill.*	Asteraceae	Herb	Native ofTropical Americal now naturalised inTropical Asia
5	*Alloteropsis cimicina(L.) Stapf*	Poaceae	Herb	Paleotropics
6	*Alternanthera bettzickiana(Regel) Voss*	Amaranthaceae	Herb	Native of Tropical Americal nowgetting naturalised inAsia
7	*Alternanthera pungens Kunth*	Amaranthaceae	Herb	Native of American; now wide spread asa weed inthe tropics and subtropics
8	*Bidens biternata(Lour.) Merr.& Sheriff*	Asteraceae	Herb	Native ofTropical Africa;Indo-Malesiato Australia
9	*Blumea laevis(Lour.) Merr.*	Asteraceae	Herb	Indo-Malesia
10	*Brachiaria ramosa(L.) Stapf*	Poaceae	Herb	Africa and Tropical Asia
11	*Chloris barbataSw.*	Poaceae	Herb	Native ofTropical Africa, spread to othertropical countries
12	*Chromolaena odorata(L.)King &H. Rob.*	Asteraceae	Shrub	Native of America; naturalised in Tropical Asia
13	*Chrysopogon aciculatus(Retz.) Trin.*	Poaceae	Herb	Tropical Asiaand Australia
14	*Crassocephalum crepioides (Benth.) S. Moore*	Asteraceae	Herb	India, SriLanka,China, Africa and Madagascar
15	*Croton bonplandianus Baill.*	Euphorbiaceae	Herb	Native of South America; now naturalised in Paleotropics
16	*Cyperus castaneus Willd.*	Cyperaceae	Herb	Indo-Malesia to Northern Australia
17	*Cyperus iria L.*	Cyperaceae	Herb	Tropical AsiaandEast Africa; introduced inU.S.Aand West Indies
18	*Cyperus maderaspatanus Willd.*	Cyperaceae	Herb	India, SriLanka and Tropical Africa
19	*Cyperus zollingeri Steud.*	Cyperaceae	Herb	Tropical Africa,Madagascar, Malesiaand Northern Australia
20	*Digitaria ciliaris (Retz.) Koeler*	Poaceae	Herb	Paleotropics
21	*Eleutherantheraru deralis(Sw.) Sch.-Bip.*	Asteraceae	Herb	Native ofTropical America; now established in several Asian countries
22	*Euphorbia heterophyllaL.*	Euphorbiaceae	Herb	Native ofCentral America; now aPantropical weed
23	*Euphorbia hirtaL.*	Euphorbiaceae	Herb	Native ofCentral America; now aPantropical weed
24	*Fimbristylis dichotoma (L.) Vahl*	Cyperaceae	Herb	Tropical Asia

25	*Fimbristylis dura (Zoll.& Moritz.) Merr.*	Cyperaceae	Herb	Indo-Malesia
26	*Hypoestessan guinolentaHook.*	Acanthaceae	Herb	Native of Madagascar
27	*Hyptis capitata Jacq.*	Lamiaceae	Subshrub	Native ofTropical America; naturalised insome parts of India and Malesia
28	*Hyptis suaveolens(L.) Poit.*	Lamiaceae	Subshrub	Native ofTropical America; naturalised insome parts of India and Malesia
29	*Ipomoea hederifoliaL.*	Convolvulaceae	Twining herb	Native ofTropical America;now naturalised inTropical Asia
30	*Ipomoea purpurea(L.) Roth*	Convolvulaceae	Climber	Native ofTropical America;now naturalised inTropical Asia
31	*Ipomoea trilobaL.*	Convolvulaceae	Climber	Native ofTropical America;now throughout the tropics
32	*Kyllingane moralis(J.R & G. Forst.) Dandy exHutch. &Dalz.*	Cyperaceae	Herb	Pantropical
33	*Lantana camaraL.*	Verbenaceae	Shrub	Native ofTropical America, widely naturalised inthe tropics and subtropics
34	*Mikania micrantha Kunth*	Asteraceae	Climber	Pantropical
35	*Mimosa pudicaL.*	Mimosaceae	Herb	Native ofSouth America;now Pantropical
36	*Pennisetum polystachyon (L.) Schult.*	Poaceae	Herb	Paleotropics
37	*Pseudanthis tiriaumbellata (Hack.) Hook. f.,*	Poaceae	Herb	PeninsularIndiaandSriLanka
38	*Pteridium revolutum (Blume) Nakai*	Dennstaedtiacae	Shrub	Tropical and sub-tropical Asia and Australia
39	*Sphagnetico latrilobata (L.) Pruski*	Asteraceae	Herb	Indo-Malesia
40	*Spilanthes radicans Jacq.*	Asteraceae	Herb	Neotropics of the world; now naturalised in Western Peninsular India
41	*Sporobolus tenuissimus (Schrank) O. Ktze.*	Poaceae	Herb	Pantropical
42	*Stachytarpheta cayennensis (Rich.) Schauer*	Verbenaceae	Shrub	Native ofTropical America;now introduced into tropics and subtropics
43	*Stachytarpheta jamaicensis(L.) Vahl*	Verbenaceae	Shrub	Native ofTropical America;now introduced into tropics and subtropics
44	*Synedrella nodiflora (L.) Gaertn.*	Asteraceae	Herb	Native of WestIndies; naturalised in India, China, Malesiaand Polynesia
45	*Tridax procumbens L.*	Asteraceae	Herb	Native ofTropical America;now widespread throughout tropics and subtropics

STRATEGIES AND ACTION PLAN FOR ECORESTORATION

One of the major objectives of this study is to provide recommendations for environmental conservation and management of the riparian areas of the Rivers in Kerala considering the impact of the August 2018 flood/landslide on the riparian flora as well as the physical impacts that occurred in that area. The overall assessment of the impact of flood and landslide on forest, riparian vegetation and agro- biodiversity brings out following recommendations.

1. LANDSLIDE HAZARD ZONATION AND ECOSYSTEM RESTORATION

There is a need to develop programmes to minimize risks associated with landslides. Strategies to manage landslide risk should include maintenance of an up-to-date landslide inventory, permanent monitoring of natural processes, studies on natural phenomena, and geomorphological mapping. Developing risk mitigation options and planning their implementation is the next logical step, followed by monitoring to facilitate programme improvement. Zoning of potential landslide areas according to risk, together with regulations excluding some activities and requiring geotechnical evaluation for others, are the most common measures for mitigating landslide risk. Control of landslides in upland areas requires an integrated approach. Tree planting alone will not solve the problem of increasing incidence of landslides and erosion. There is also need for landscape-level planning of land use, good land management practices in cropping, grazing and forestry, careful road construction, terracing and other contour-aligned practices in fields and plantations, and participation of local communities. Within agricultural and other areas, individual slopes with unstable soils or perched water tables in topographic depressions are best left as forest, or reforested if already cleared, due to the high risk of landsliding.

Bioengineering techniques for stabilization of landslide susceptible areas.

1. **Slope stabilization through contour wattling, mulching and planting:** Seeding with grasses and legumes reduces surface erosion, which can under certain conditions lead to landslides. Planting with shrubs adds vegetative cover and stronger root systems, which in turn will enhance slope stability. If not controlled, surface erosion and small, shallow slope failures can lead to larger problems that cannot be controlled. Controlling surface-water drainage, removing cut-bank overhangs, reducing slope angles, and benching all should be done before seeding begins. As part of site-specific activity in major landslides, Contour wattling along with mulching and planting is of great help. This technique comprises breaking the length of slope into shorter stable portions by providing contour wattles, mulching the inter wattle

area and effective plantation. On the downhill side trench, species such as *Lannea coromandelica*, *Gliricidia sepium* etc. can be placed in the trenches at 100–125 cm interval.

2. **Excavation and fill:** These are an important aspect of slope modification. Slope stability can be improved by removing of the entire slide mass, reducing the height of the slope, back filling with lightweight material, constructing benches, flattening the slope angle. The selection of technique should depend on the type of landslide and cost effectiveness.
3. **Slope stabilization and erosion control by coir netting or Jute geo-textiles:** After grading the slope, the seed are sown, and organic manure is applied. Two sowing are done, one before netting and the other after laying of coir netting. The coir netting is firmly laid on the prepared slopes toward water flow. The successive widths of coir netting carpets are secured against displacement by an overlapping of about 8 cm. They are pegged down with staple driven 30 cm apart. Germination of grasses in areas treated with geojute is suggested.
4. **Ecorestoration with native species:** Ecorestoration and planting of species on landslide degraded areas shall follow a suitable ecorestoration or species selection protocol. Bench mark data collection, selection of proper species suitable to the bioclimate and approval from BMC/LSGs shall made mandatory. Planting of non native / exotics shall not be promoted. A combination of local species along with other species is necessary to regenerate the affected area close to its native form. The selected species should have deep and large root system and preferably be hardy, fast-growing and suckering. When properly installed and maintained, vegetation could protect slopes by reducing erosion, strengthening soil, and inhibiting landslides which increase general slope stability. In general the key parameters to be considered are:
    - Good survival and growth on poor sites;
    - Ability to produce a large amount of litter;
    - Strong, deep and wide-spreading root system with dense, fibrous roots;
    - Ease of establishment and need for minimal maintenance;
    - Capacity to form a dense crown and to retain foliage year-round, or at least through the rainy season
    - Resistance to insects, disease, drought and animal browsing;
    - Good capacity for soil improvement, e.g. high rates of nitrogen-fixation, appreciable nutrient content in the root system;
    - Provision of economic returns or service functions (quickly) such as fruit, nuts, fodder,
    - Low invasiveness

MAJOR RECOMENDATIONS

1. Microlevel landslide hazard zonation map of all LSGs in a 1:2500 scale (2.5 m spatial resolution) to be prepared which will help in spatial planning for avoiding un-sustainable and non-resilient developmental activities.

2. A ground survey should be done to understand the hazard susceptibility zones in each LSGs and efforts to record events of all land movements, particularly in very high and high hazard zones should be undertaken. This which will help BMCs and LSGs while taking decisions on developmental activities.
3. Systematic updation of PBRs on grid basis so that it can be used as a ready reference for natural resource and land use change for preparing Landscape level Local Action Plan for Biodiversity (LBSAP).
4. No actions which alter the topography of areas prone to hazard should be allowed without impact study as pointed out in studies conducted at Thirunelli, Thavinjal, Thariyode, Pozhuthana, Vythiri and Meppadi regions of Wayanad.
5. It is recommended that any further construction or activities which cause slope destabilization in high risk zone for landslide susceptibility should be avoided and these people living shall be rehabilitated to more safer areas. For eg In Wayanad Sughandhagiri Anpethu acre region is one of the most affected areas with several landslide events resulting in the loss of houses of tribal people in the land given to them under Forest Rights Act 2006 and efforts should be taken to increase the canopy cover in this region. Regions as Makkimala region should be declared as Ecologically fragile Land.
6. One of the best approaches to enhancing slope stability, while also promoting biodiversity conservation, involves restoration of upland forest ecosystems. A greater diversity of forest species improves slope stability through more complete use of available rooting zones. Inclusion of fruit trees or species that provide products without the need for felling can also support socio-economic needs.
7. Athirapilly Grama Panchayath was affected by 28 landslides which has resulted in a loss of 283.72 ha of land and restoration activities has to be undertaken in prioritized areas . Since most of the landslides occurred in the forest area (95%) and the Anamalai road traversing the forest areas at different hilly terrains the restoration of landslide areas has to be brought into the priority action list of LSG as well as Forest Department and PWD. The location of prioritized areas including GPS readings, dimension and configuration including slope and adjacent landuse is suggested in the study
8. The road construction along the steep terrains require much physical support for the embankments, which can support prevention of landslip as well maintain growth of vegetation cover.
9. Necessary pathways for movement of animals especially larger mammals like elephants as well as arboreal species are required across the roads with steep slopes and hairpin bends. The embankments shall be provided with gaps which enable movement of ground dwelling organisms.
10. Proper management of waterways across the roads is also a necessity i.e the dimension of the Chappath or Culverts shall be made assessing the order, slope and water level in the extreme monsoon.
11. The steep cutting or the straight running streams in very hill terrain are also found to be causing landslides and chance increases with degraded landuse and slope. These areas shall be notified as 'Vulnerable zones' and since such areas are more prone to landslides, making residential zones downstream to such areas should be avoided. Intervention in landuse pattern leading to degradation in such areas shall be prevented.

12. The hills and hill slope shall maintain at least 30 % natural vegetation or mixed cropping including diverse natural tree growth.
13. Clearing of the natural vegetation at the top of the hills shall be banned and ecorestoration of natural vegetation shall be promoted in hills tops.
14. A Total of 5 landslides occurred in residential areas one in Non- tribal land Pandarampara and 4 landslides occurred in the tribal agricultural land mainly in Thavalkkuzyppara, Anakayam, Adichilthotty and Kappayam of Athirapally. Special action plans has to be developed for the restoration of the residential as well as agricultural areas in these locations.
15. One of the high impacted landslides occurred at Pandarampara area near Vettikuzhin in the 1st ward of the Athirapilly Grama Panchayath. This has completely washed out the agricultural crops from this area mainly rubber, arecanut, coffee nutmeg etc. Quick normal recovery is not possible in this site
16. The Anakkayam Tribal settlement is badly affected due to a clustered huge landslide that happened along the Anamalai Road in the Anakkayam Valley. Being a PVTG tribal group with special right under FRA 2006 including the CFR and habitat right their Grama Sabaha has to be consulted to prepare a proper relocation plan. Since the individual land claims of the Anakayam settlements were settled, CFR claims are recognised and they are protected from resettlement from their original habitat under habitat right of FRA 2006, they can be given equal land in which they have the titles in locations where their Grama Sabha propose to have a new settlement. The Grama Panchayath has the authority to initiate the process under the act.
17. Incentives have to be given for landowners and community involved in protection of natural vegetation in the hilltops, practising mixed cropping with at least 30 % of the area of natural native tree growth along hills, Protection, monitoring and sustainable harvest practice of riparian areas. The incentives can be a minimum of MNREGS wages for the family who endorse for the activities.

2. ECO RESTORATION OF WETLAND ECOSYSTEM

Since the riparian vegetation is more resilient to the flood impact and they functioned well in the areas preventing further damage to the river and riverine biota restoration of the damaged riparian areas and their monitoring based on a detailed plan is a necessity. Based on the case studies conducted in 9 rivers the recommendations for conservation and management is suggested.

Major Recomendations

1. Removal of riparian vegetation in the public places shall be banned or that has to be based on a sustainable harvest plan developed by riparian community associations and recognized by each BMC and local bodies.
2. Construction of any kind may be banned in the vicinity of river including that on the river banks. Instead the banks of the river may be strengthened with plants such as different species of bamboo, Pandanus etc.
3. A river basin- watershed level approach for development planning and approval from LSGs/River Basin advisory body has to be made mandatory

4. Remove physical barriers from water channel (sand/alluvial bars) and those which alter the geo-morphology of river
5. Restore the original guard vegetation after creating appropriate edaphic management and initiate river bank protection by suitable plant species.
6. Ecorestoration of species planting shall follow an ecorestoration protocol based on the pre existing or currently existing species as per bench mark data collection and as approved by BMC and LSGs. The BMCs can take initiatives to make action plans for ecorestoration and monitoring programs incorporating MNREGS.
7. Giving more popularity for the requirement of Ecorestoration and Ecological monitoring involving local community, students, women groups and indigenous communities in the awareness programs is necessary.
8. The riparian ecorestoration and monitoring plan of Athirapilly Gram Panchayath in the Chalakkudy River suggest involvement of riparian BMCs, Local Self Governments, Tribal GSs, CFRMCs/FRCs, VSS/EDCs and other riparian community associations through developing a Local Body level plan using the Ecorestoration protocol including development of an online module with Kerala State Biodiversity Board as a monitoring agency.
9. Declaration of the Riparian forest areas along with river stretches into a Community protected area eg : the unique low elevation riparian forests in the Athirapilly Grama Panchayath and the nesting sites of Hornbill protected by Kadar indigenous community
10. Restoration activities at important streams and watersheds including conversion of some teak plantation into natural forests are necessary for reducing water scarcity in summer. The water scarcity due to plantations are the major reason for wildlife attack
11. Since the Tribal population of Athirapally Panchayath depend more on forest and biodiversity for it livelihood, a perspective plan for the Panchayath based on organic farming, ecotourism, biodiversity conservation etc need to be developed with leadership of LSG and BMC members with support of experts.
12. Plants able to fix atmospheric nitrogen are to be included as intercrops in the eco-restoration programmes and farming activities in the river basin.
13. Any eco-restoration programmes in the flood affected river basins may take support from soil microbiologists.
14. A detailed survey should be carried to demarcate the small and large sacred groves, ponds and streams associated with the rivers, especially in Pampa and Achencovil. The specific indigenous flora and fauna of such ecosystems should be understood to prevent their degradation by human intervention in such areas. Declare such areas as special ecological zones and protect them.
15. Prevent large-scale unscientific collection of river sand for construction purposes.
16. Many landslide events occurred in the catchment areas of river Pampa and Achencovil during the flood. This caused the erosion of top soil and complete removal of shoreline plants, which were supposed to protect the soil from erosion. So proper catchment restoration planning should be done for the identified sensitive areas. Stone protection wall should be made in such areas. Also a thick belt of selected plant can be grown in such areas to prevent the damage caused due to strong flow of

water. Small soil traps ("Manchira") should be made in private land areas associated with riverbanks. This helps to hold large quantity of running water during rain as well as help in water movement to deep soil.

17. The riverine ecosystem in the 12 Panchayats of Pathanamthitta district are very fragile with low to severe damages along the sides. In order to address this perennial issue, a long-term strategy is to be planned with bio fencing and dry rubble masonry work along the flood escape routes. It is advised that dry rubble masonry be done in consultation with the Irrigation Department at all vulnerable points. Further, it is suggested that the plants selected for planting along the river banks should have a short stature and ramified root system to protect the embankment.
18. In Manimala river basin most of the damage has happened in and around areas of higher anthropological activities like construction of roads.

The suggested species and their characteristics are

- *Ochlandra travancorica* (ideal for lower and upper river banks), culm height 6M, diameter 2.5-4cm, lifespan 40 years, high density planting with 2M spacing.
- *Dendrocalamus strictus (*ideal for terrace face and upper terrace face), culm height 9M, diameter 3-5cm, lifespan 60 years, plant with 4M spacing.
- *Bambusa balcooa* (ideal for terrace face and upper terrace face), culm height 12-15M, diameter 6-6.1cm, lifespan 40 years, plant with spacing of 6M.
- Other suggested species for this purpose are Attuvanchi, and Ramacham. High density planting of bamboo trees along the riverine areas are to be attempted at a spacing of 2 x 2 M with the help of MNREG. The flood escaping routes identified with the Pampa river are 1. Varattar 2. Uttathra Palliyar 3. Illimalathode 4. Kuttanperoor river 5. Arithod Kolara river . These rivulets should be rejuvenated by clearing the routes of weeds and obstructions.

19. Alapuzha – Changanacherry canal from Kidangara to Pallathuruthy covering a distance of 22km is supposed to siphon off the floodwater from Upper Kuttanad area. But in this stretch it is noted that only 13km of the canal work has been completed from Kidangara. The remaining 9km canal work is yet to be completed. Once completed, this will mitigate the severity of flood impacts of Pathanamthitta district considerably
20. In the informal consultations with local body representatives during the study, most of the people has suggested that some of the issues affecting river health like hospital waste management, workshop waste management, sand, clay and mining etc. have to be mainly controlled through creating awareness and by strict enforcement of legal measures by the local bodies and concerned departments.
21. Kattampally wetlands consists of variety of habitat from fresh/ brackish water swamp, tidal marshes, sub-tropical secondary scrub, paddy-fields and mangroves. During the course of the survey, land filling was sighted at two locations at Kattampally. There

are more of such kind of fillings being done at various locations in Kattampally that has been reported by locals. Strict actions should be taken to counter such wetland filling activities. The State Wetland Authority Kerala (SWAK) and The Biodiversity Management Committee (BMC) of the Panchayat has to take note of such illegal activities and take necessary course of action against the defaulters jointly with other concerned.

22. During mid March, the paddy fields are set on fire. This deliberate burning is done across the farm lands of Vemband and Upper Kuttanad. Earlier, the straw was collected separately manually during the harvest itself and used as cattle feed in the local households or taken in bulk by companies to make cardboard. But now, most farmers rent a Combine Harvester, which leaves up to 80% of the residue in the field. With the increase in the usage of mechanical tractor, this issue has further escalated as the residual straw left behind after the harvest makes it difficult for the tractor to plough the land. Apart from this, a study suggests that burning of straw reduces soil quality. Razing of 1 ton of rice straw results in the loss of 5.5 kilograms of nitrogen, 2.3 kilograms of phosphorous, 25 kilograms of potassium and 1.2 kilograms of sulphur. Awareness programmes have to be conducted to sensitise the farmers about the consequence of stubble burning on the ecosystem, its inhabiting life forms, on the environment and their health. The farmers should be provided with an option to either sell the straws or an alternative has to be made where they can turn the straw to a value added product
23. Pookot Lake: The Lake is the only recorded habitat of the critically endangered Pookode barb (Pethia pookodensis). All efforts should be focused in the rejuvenation of the lake which is critical not only for the Pookode barb but for the numerous life forms that thrive in and around the lake. The survival of the lake is also critical to the water table in the area and hence is of serious concern for the local inhabitants.
    - Appropriate studies and consultation should be taken before undertaking any construction activities, especially one involving alteration of habitat. Measures should be undertaken to restore the habitat around the lake. The elevated pathway around the lake and tiles should be modified to allow water seepage in to lake.
    - Steps should be taken to limit tourist entering the premises at a time based on carrying capacity study of the lake
    - Presently the Ecotourism in and around Lake is limited to adventurous activities. Steps should be taken to expose tourist especially students to biodiversity and ecosystems in and around the Lake (Bio-education tourism). This can be done through guided transect walks and small classes or video sessions.
    - Appropriate field guides and awareness material for biodiversity conservation shall be prepared for this. Bio-education tours can include frog trails, bird watching, butterfly watching etc.
    - The health of the lake has to be monitored periodically and steps should be taken for the timely removal of algal weeds and other invasive species.

- There are solar lights erected on poles at some points around the lake. This could cause disorientation to moths and other night flying invertebrates. Hence it is recommended to switch off after initial hours.
- Aquatic/ wetland rejuvenation protocol should be adopted.
- Aquarium of Native fish species can be established.
- Native water plant conservatory with technical guidance of Institutes like Malabar Botanical Garden can be established.
- Adjoining landscape conservation shall be promoted including the nearby grasslands.
- Peoples Biodiversity Register containing information of local flora and fauna shall be updated regularly and used as a tool for Biodiversity Monitoring
- Biodiversity Management Committees are the Environmental watch group of the locality and they shall be involved in all Conservation activities of Pookode lake.
- The Fisheries Department has introduced cage culture in the Lake for Cyprinus species, whereas ideally it is not advisable to introduce cage culture into freshwater lakes for the reasons of easy spread of diseases and chances of captive fishes escaping from the cage into natural waterbodies and competing with other endemic species. The health of the Lake has to be monitored periodically and steps should be taken for the timely removal of algal weeds and other invasive species, which would help native species to regain their lost abode.

3. RIVER MANAGEMENT ACTION PLAN AND IMPLEMENTATION

The suggested management action plan is based on the scientific concept that the rivers act as a holistic system wherein any change at any part of the basin has repercussions in other parts of the basin and wellness of the system. Accordingly, the study suggests that any management program should take into account the basin scale processes and basin-wide responses of the river system for effective management. The study indicates that the growing population and resultant anthropogenic interventions in the name of developmental activities along with climate change and extreme events has made many changes in the land use and land cover. The long term management plan has to address the issue with all scientific data. **T**he major components of the ecosystem based approach are:

- Watershed Management-Streams, Drainages, wetlands
- River Water Management -Water Quality, Waste disposal, Flow Modification, Channel Reconfiguration, Fish Passage, In-Stream Species Management, Dam Removal/Retrofit, Floodplain Reconnection, In-Stream Habitat
- River Bank Management - Bank stabilization, Riparian Management
- Environmental sustainability of the entire basin area
- Socio-economic Considerations: Wise use of wetlands - Heritage/ Aesthetics/ Recreation/ Education /Land Acquisition
- Proper awareness creation and capacity building of various stakeholders

Based on the above criteria, the study has developed a detailed framework for developing of a management action plan for the reviving the Rivers of Kerala to be initiated and implemented by the local bodies by strengthening the BMCs with active participation of KSBB and other institutions as mentioned in the framework .

3.1 AWARENESS CREATION AND CAPACITY BUILDING

The awareness and capacity level of different authorities and the public has to be improved for managing the river basin in an effective manner. It is necessarily a long, carefully considered process, which requires careful planning for which an Information Communication and Education (IEC) strategy has to be developed. Periodic monitoring of river basin is also an essential component of river conservation. This will help the stakeholders for better understanding on the issues and reduce the impacts. The present study suggests the following programmes for awareness creation, capacity building and proper monitoring:

- Availability of systematic and temporal data – There are many studies related to fauna and flora taken up at different levels by individuals, institutions, NGOs, University Departments, research scholars etc. in different time frames. It is recommended that standard and uniform protocols has to be designed for surveys on flora and fauna groups and reports have to be made available in an authorized online database.
- Ensuring more accessible information sharing mechanism and facilities for river monitoring by establishing an Environmental Knowledge Hub (EKH) with emphasis to river management and monitoring, this will cover almost all areas related to environment.
- Identification of local resource persons covering various aspects of river/environmental management.
- Establishing tie-up with academic/research organizations in and around the local body and developing facility for periodic water/soil sample testing, sharing popular scientific reading materials etc.
- Setting up a permanent exhibition on river basin management with particular reference to the river flowing through the local body and preparation of leaflets
- Conducting regular training/refresher programmes for village volunteers and officials

3.2 River Pollution Issues

Cleaning of water bodies: Strategies has to be developed for cleaning these water bodies with the participation of local people, academic institutions, community organizations, NGOs etc.

Solid Waste Management: The key approach to sustainable solid waste management shall be based on decentralisation, community participation, location specific technologies and convergence of activities of various agencies. household wastes can be managed there itself; or it can be collectively managed at the Neighbourhood Groups level or at the community level for 200 - 300 households.

Community based initiatives like Biomethanation, Aerobins (Thumburmuzhy model), Biobins (CREDAI Model) etc. are also are practiced very efficiently in the State in various places. There is also a need to induce proper interest in the activity and willingness to participate. This can be developed through proper awareness programs through the village environmental hubs.

Liquid Waste Management***:*** Another major issue in River pollution is the direct discharge of waste water to the streams and Rivers. To overcome the consequences of water scarcity, the concept of grey water (domestic waste water except from toilet) reuse might be thought as a solution besides rainwater harvesting and other conservation methods.

Animal Slaughtering Wastes: Establish a common slaughter house with necessary facility in a suitable location which can be utilised by two or more local bodies. Maintain slaughter sheds with minimum facilities ensuring hygienic condition and transport the waste to a central facility to be established along with the solid waste management plant

3.3 Developing a Catchment Area Treatment Plan

The catchment area treatment (CAT) plan pertains to preparation of a management plan for treatment of erosion prone area of the catchment mainly through biological and engineering measures. In general, the catchment area treatment for steep slope and highly dissected areas should have a ridge to valley approach in an integrated manner; thereby the upstream portions of tributaries will be subjected to treatment first. Natural vegetation cover with protection and correction of drainage channels is the ideal condition for slope stability.

- The existing natural vegetation both in good and degrading state should be preserved and further degradation and fragmentation should not be allowed
- Checking Drainage Obstructions and Ensuring Free Flow in the Streams: Most of the streams are now blocked by construction of buildings, roads etc. These areas shall be identified by using drainage maps of the basin based on which, concentrated efforts are to be undertaken to remove the blocks by people participation.
- Clearing of degraded forest for plantation development should be strictly controlled and intervention in the demarcated critical zones restricted.
- The exposed hill slopes should be vegetated with grass cover so as to minimize soil erosion.
- Afforestation and vegetative bunds should be practiced wherever possible with locally growing plants
- Careful planning to prevent the outbreak of forest fire especially in the hill top grasslands by ensuring annual fire protection works.
- Traditional agricultural practices like base trenching , mulching and growing cover crops should be promoted in all areas.
- Drainage line treatment with a combination of vegetative and engineering structures, such as earthen checks, brushwood checks, gully plugs, loose boulder checks, gabion structures, under dykes etc.
- Tiny overflowing type conservation schemes are proposed for second and third order streams for in situ conservation of soil.

- In high slope areas contour bunding and terracing carried out as part of soil conservation measures sometimes promotes debris flows. Provision is needed in such slopes for safe runoff passage, to reduce over saturation of the soil. All the natural drainage lines in such areas, both micro and macro has to be preserved and no diversion effected during bunding or terracing.
- Contour trenching for checking the velocity of runoff in the ridge area of any watershed.
- Ecofriendly check dams with Gabion technology shall be constructed in the Main River and major tributaries, based on detailed study.
- Promoting rain water harvesting and well recharge utilizing the Mahatma Gandhi Rural Employment Guarantee Scheme (MGNREGS)
- Rejuvenation of degraded ponds and construction of new ponds : Pond rejuvenation and constructing new ponds is another activity which has to be promoted for sustainable water management through ground water recharging. The study recommends the following in this regard. 1) Conduct local body ward level surveys with people participation for ascertaining the present status of all ponds. 2) Rejuvenate one pond in each ward with earthern bunds and vegetation as a model 3) Identify areas for new ponds through scientific methods using the TIN and DEM map etc. and develop ponds in an Ecofriendly way.

3.4. Riparian Area Management

Major issues identified in Riparian areas :

1. River Bank Slumping/Erosion
2. High Deposition of sand and mud on the banks
3. Loss of vegetation including plants with high conservation values
4. Spread of Invasive species

River Bank Slumping/Erosion : Bank slumping or bank collapse is a form of mass failure where large chunks of bank material become unstable and topple into the stream or river in single events. In general, the erosion are mainly due to the main river traversing through a series of deep and narrow trenches created in the river course, over-clearing of catchment and stream bank vegetation, poorly managed sand and gravel extraction, and stream straightening works which result in accelerated rates of bank erosion. , The formation of sand bar in the midst of the river during flood can trigger bank erosion in future also.

In many areas the reason for severe erosion in the main river banks is attributed to the uncontrolled sand mining from the river. The removal of riverside vegetation is also a major reason for erosion and bank slumping. The present practice of removing all the vegetation and trees from the banks of the streams as part of the cleaning of streams in many Panchayats under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) is now emerging as a major threat to the streams, creating erosion and subsequent slumping of banks. The present bank erosion control structures and programmes are not only very expensive but also are not compatible with environmental and aesthetic concept.

There is an immediate need for protection of some highly eroded areas mainly in some bathing ghats and ferry points and in the major streams. In the highly eroded areas, the study suggests the protection of lower parts with gabions and upper portion with plants. In some areas provisions for bathing, ferrying etc. is also to be provided. The mildly affected areas in the stream need only protection through vegetation. The main reason for suggesting a vegetative method for protection is to reduce surface erosion and nutrient load and enhance the water quality.

High Deposition of sand and mud on the banks: High deposition of sand and mud on the banks is noticed in many places. The removal of this material requires proper scientific studies by experts in this area.

Site specific species plan and enrichment is important in ecorestoration of degraded riparian vegetation. A detailed study of the bioclimate and vegetation only can provide the possible climax vegetation composition of an area or a landscape. This shall include the following steps

i. ***Assessment of Vegetation for Preparation of Ecorestoration Protocol (ERP) (Bench mark Data Collection) including vegetation and species priority checklist.***

   b. Understanding bioclimate and corresponding potential climax vegetation
   c. Gathering benchmark data
   d. Grading the existing composition from pioneer, degraded or seral to climax vegetation.
   e. Preparation of species composition corresponding to each vegetation and subtypes and species priority checklist

ii. ***Sampling of proposed ecorestoration area and preparation of site specific plan (SSP) through selection of species from species priority checklist of ERP.***

   a. Identification of degraded areas or areas that need ecorestoration (GPS mapping etc)
   b. Compartmentalization based on administrative divisions for planning and implementation
   c. Field visit and sampling for understanding existing species composition (15 x 20m) sample plots at three different areas 1. Heavily degraded zone, 2. Partially degraded zone and 3. Heavily degraded area
   d. Analysis of data and species composition
   e. Comparing with vegetation species composition checklist and selection of species from corresponding or at least one seral stage towards climax composition

A quick assessment (Preliminary SSP) can be made through photo documentation, GPS records and transect walk for the preparation of a proposal. A proposal for ecorestoration shall contain at least ERP and a preliminary SSP and the detailed SSP can be done during the time of implementation prior to the last phase (iii. Planting and monitoring)

iii. Planting and monitoring

1. Collection and preparation of seeds (propagules) or seedlings Preparation of nursery (shall be close to the site and within the bioclimatic area)
2. Planting of seedlings (involvement of local community)
3. Monitoring regular perambulation, monitoring and replanting (1-3 years involving local tribal community)
4. Monitoring and protection (3-7 years, involving local tribal community)
5. A journal has to be kept suitable for recording the monitoring data at each sites

iv. Community involvement

The process of ecorestoration has to be completely community involved. The BMCs of each Panchayath can take initiative and identify particular locations for ecorestoration and organize local community incorporating i. Tribal or indigenous community, their Grama Sabhas (GS), Forest Right Committee (FRC) or CFR Management Committee (CFRMC) statutory bodies in the tribal dominated forest area, ii. VSS/EDC in non tribal forest area, iii. Local fishing, agriculture community, farmers in non forest area, iv. Riparian land owners, v. MNREGS workers of the area. These communities can form the riparian ecorestoration community for a particular zone. Similar such stakeholder communities can be organized under each BMC and LSG. The nursery development, planting, Protection and monitoring need involvement of local communities especially tribes or SC community if any.

3.4.1. Selection of species for ecorestoration

Ecorestoration require restoration of species suitable to the local bioclimate and succession stages from local gene pools and not mere planting of some easily available species . The species selection methodology is very important which can help for selection of site specific species suitable to the bioclimate and vegetation type.

Important protocols for Nursery development

- A riparian species data bank with respective riparian forest community composition can be developed as an online data base.
- During nursery development a permanent seed-mother bed has to established first inorder to put seeds (evergreen species) immediately after collection.
- The nurseries has to be established in areas near to the corresponding vegetation type or same bioclimate either near the vicinity of forest stations or VSS / FRC.
- Soil can be collected from boundaries of adjacent forest areas and adequate watering facilities are required
- The best time of collection of seeds would be February – May for deciduous species and April-June for evergreen species.
- Collected seeds have to be put on separate labeled areas of the mother bed in order to identify germinating seedlings.
- This can be transferred in to carry bags with larger dimension later.
- The seedlings at least need one year of growth before planting.

- For the evergreen species casualties may be high so 20% additional seedling in the mother bed are required and some easily establishing, pioneer species could be used.

Ecosystem-Based Solutions with resilient taxa should be developed for the recovery of affected and risk-prone areas and reducing further damages. The affected areas as also the species to be planted should be prioritized for ecorestoration activities. It was observed that some panchayat are implementing schemes for planning vetiver in landslide/slip affected areas, which they consider as a supplementary income source for local people after two years. But the uprooting of vetiver from slopes will cause the soil's loosening leading to erosion. For the restoration of the land close to its natural conditions, site-specific structural composition should be studied, and species seen in those areas should also be added in the restoration programmes for the recovery of the regions in a way to have a healthy ecosystem which will be able to deliver all the ecosystem services. Reforestation programmes must be initiated with location based taxa that got disrupted

The present study has identified and prioritised number of species suitable for various locations depending upon the bank condition, utility etc. and this can be used for various river bank afforestation programs.

Riparian ecosystem enrichment can be done by planting riparian species like *Anthocephalus cadamaba, Ochreinuclea missionis, wild Mango, Bamboo, Pandanus species, Ochlandra species, pongamia pinnata, Crateva magna, Trewia nudiflora, Terminalia cuneata, Homonoia riparia, Salix tetrasperma* etc. Planting grasses with deep root system like *Vetiveria zizanioides*, some other locally available native species (*Bauhinia variegate, Ipomoea aquatic* etc.) can help preventing erosion.

Suggested species - Wayanad

1. Bambusa sps.
2. Bischofia javanica Blume
3. Callicarpa tomentosa L.
4. Carex baccans Nees
5. Chrysopogon aciculatus (Retz.) Trin.
6. Chrysopogon zizanioides (L.) Roberty
7. Crotolaria sps.
8. Cymbopogon citratus (DC.) Stapf
9. Cymbopogon flexuosus (Nees ex Steud.) Wats.
10. Cymbopogon nardus (L.) Rendle
11. Cynodon dactylon (L.) Pers.
12. Dalbergia latifolia Roxb.
13. Desmodium sps.
14. Digitaria ciliaris (Retz.) Koelersp.
15. Digitaria longiflora (Retz.) Pers.
16. Diospyros ovalifolia Wight
17. Ficus sps.
18. Hopea sps.
19. Hypolytrum nemorum (Vahl.) Spreng.
20. Imperata cylindrica (L.) Raeusch.
21. Ochlandra sps.
22. Mallotus tetracoccus (Roxb.) Kurz
23. Mallotus philippensis (Lam.) Muell.- Arg
24. Macaranga peltata (Roxb.) Muell.-Arg.
25. Olea dioica Roxb.
26. Sapindus trifoliata L.
27. Strobilanthes sps.
28. Symplocos cochinchinensis subsp. laurina (Retz.) Nooteb.
29. Symplocos racemosa Roxb.
30. Terminalia paniculata Roth
31. Vateria indica L., etc. along with the innate species.

Resilient taxa in Akamalavaram section, palghat gap

Thorough field explorations in the flood affected sites documented a list of survival taxa which includes *Ailanthus excelsa, Bambusa bambos, Dillenia pentagyn, Ficus hispida , Ficus microcarpa, Calycopteris floribunda, Mallotus philippensis, Spatholobus parviflorus, Tectona grandis, Syzygium cumini, Dalbergia latifolia, Terminalia paniculata, Ficus racemosa., Anogeissus latifolia, Xylia xylocarpa,Tectona grandis, Sapindus trifoliatus and Dalbergia sissoo.* Some climber taxa such as *Spatholobus parviflorus* and other trees such as *Syzygium cumini (L.)Dalbergia latifolia* 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.

Species for restoration in Manimala river

Pandanus furcatus, Talipariti tiliaceum, Thespesia populnea, Ochlandra sp., Ficus exasperata, Ochreinauclea missionis, Hydnocarpus macrocarpa, Humboldtia decurrens, Vateria indica, Hopea erosa, Cinnamomum perrottetii, Ficus exasperata, Ochreinauclea missionis

Suggested species Athirapilly Grama Panchayath – Vazhachal

1. *Auxonopus compressus*
2. *Kyllingia brevifolia*
3. *Desmodium trifolium*
4. *Cassia tora*
5. *Ludwigia ascendens*
6. *Mollugo oppositifolia*
7. *Centella asiatica*
8. *Hedyotis corymbosa*
9. *Eclipta prostrata*
10. *Elephanto pusscaber*
11. *Scoparia dulcis*
12. *Hygrophila ringens*
13. *Hygrophila schulli*
14. *Boerhaavia hospita*
15. *Aerva lanata*
16. *Polygonum barbatum*
17. *Polygonum glabrum*

3.4.2 Monitoring and Protection

Comparison of climax to degraded and seral vegetation compositions with proper statistical support and mapping tools indicated following degradation factors 1. less extent or absence of vegetation cover, 2. Nature of degraded adjacent forest types 3. Catchment degradation and loss of perenniality of streams. 4. Stream flow diversion by dams and reservoirs and subsequent drought or loss of perinniality. 5. Flow regulation by reservoirs and power houses hence the flood impact on vegetation and seedlings dynamics 6. Fire degradation, 7. Spread of weeds, 8. Grazing by wild/domestic animals, 9. Normal death and decay of seedlings or saplings planted, 10. Non-sustainable Harvest of the plants of plant parts by local community. This can be monitored using the monitoring protocol / journal / online facility with mobile photograph and weightage ranking. Families of local community from the above mentioned riparian community group shall be engaged turn-wise in monitoring of a particular area.

The Local bodies, local NGOs (Puzha samrakshana samithy, Kayal samrakshanasamity), BMCs, Residential associations, Fishermen societies, bodies of temples,churches and mosques on the bank etc ., may be entrusted.

Riparian plants for Afforestation
Moist deciduous riparian species for heavily degraded areas

1. Pongamia pinnata - Vungu
2. Gmelina arborea- Kumbil
3. ateria indica – Vellapain
4. Hopea ponga - Thambakam
5. Machilus macrantha - Kulamavu
6. Terminalia paniculata - Neermaruthu
7. Tetrameles nudiflora - Cheeni
8. Trewia nudiflora – Pambara kumbil
9. Lagerstroemia microcarpa – Vnthekkue
10. Lannea coromandelica - Kalasu
11. Glochidion zeylanicum - Neerola
12. Bombax ceiba – Elavu
13. Bamboosa bambos - Mula

More moist environments & enhancement of already existing Moist Decidious riparian vegetation

1. Mallotus atrovirens - Sindhuram
2. Hydnocarpus pentandra - Marotti
3. Ochlandra spp. - Eetta
4. Vateria indica – Vellapain

Low-elevation evergreen riparian species

1. Vateria indica – Vellapain – fast growin
2. Elaeocarpus tuberculatus – Puzhathanni, Bhadraksham
3. Barringtonia acutangula - Attupezhu
4. Bombax ceiba – Elavu
5. Cinnamomum malabatrum – Vayana
6. Dipterocarpus indicus – Kalpayin
7. Elaeocarpus serratus var. serratus- Kara
8. Garcinia gummi-gutta – Kudapuli
9. Madhuca neriifolia – Attilippa- ST – true riparian
10. Mallotus atrovirens - Sinduram
11. Schleichera oleosa - Puvvam
12. Stereospermum colais var. colais – Pathiri
13. Flacourtia Montana - Lubikka
14. Xanthophyllum arnottianum – Madakka
15. Poeciloneuron indicum – Poothamkolly
16. Diospyros crumenata – Karimaram , Karimbudan
17. Calophyllum calaba – Chrupunna
18. Ochreinauclea missionis - Attuvanchi

For heavily degraded areas with enough soil depth

1. Gmelina arborea- Kumbil
2. Holigarna arnottiana - Cheru
3. Hydnocarpus alpina _ Marotti – Vetti – ST
4. Polyalthia fragrans - Nedunar
5. Tetrameles nudiflora - Chini – for rocky most areas

Wet evergreen riparian forest

1. Vateria indica – Vellapain – fast growing
2. Canarium strictum – Thelli – Black damme
3. Mesua ferrea - Nanku – Churuli
4. Knemma attenuata – Chorakali Chorapathri- Ende. WG,
5. Myristica beddomei - Pathripoo – True riparian
6. Myristica malabarica- Apthripoo - Endangerd
7. Turpinia malabarica – Neerthani- Ende. SWG,
8. Garcinia gummi-gutta – Kudappuli
9. Cullenia exarillata – Vediplavu – Karani
10. Dysoxylum malabaricum – Vellakil
11. Diospyros paniculata

For heavily degraded wet-evergreen riparian areas

1. Vateria indica - vellapain
2. Lagerstroemia speciosa - Manimarutu
3. Knemma attenuata – Chorakali
4. Litsea coriacea – Chevukodi
5. Salix tetrasperma - Attuvanchi

Species of rare, endangered, threatened and endemic category suitable for planting along the evergreen riparian areas

1. Aglaia barberi – Akil- Ende. SWG, R
2. Aglaia lawii – akil , Ende. WG, R
3. Baccaurea courtallensis – Muttilthuri- Ende. WG
4. Calophyllum calaba L., Cherupunna -Ende. SWG,
5. Calophyllum polyanthum – Punnapam-, Ende.SWG,
6. Chionanthus mala-elangi – Kallidala- Ende. PI,
7. Cinnamomum malabatrum – Vayana- Ende. WG,
8. Cinnamomum riparium – Attukaruka - Shrub-ST- Vulnerable
9. Cullenia excarillata – Mullanpali- Ende. SWG,
10. Dysoxylum malabaricum – Vellakil-, Ende. SWG
11. Garcinia morella –

12. Hopea parviflora – Thambakam, Endangered
13. Hopea ponga – Irumbakam, Thambkam, Endangered
14. Humboldtia vahliana – true riparian & Rare
15. Hydnocarpus pentandra – Marotti - MT
16. Kingiodendron pinnatum - Kulavu- Ende. PI, E
17. Knemma attenuata – Chorakali-Chorapathri- Ende. WG,
18. Myristica beddomei - Pathripoo – True riparian
19. Myristica malabarica- Apthripoo - Endangerd
20. Myristica malabarica – Pathripoo-, Ende. SWG, V
21. Ochlandra scriptoria – Odal- Endemic to SWG
22. Ochreinauclea missionis – Kadambu-, Ende. SWG, V
23. Polyalthia fragrans - Neduar - Annonaceae, Ende. SWG,
24. Syzygium occidentalis - Attuchamba - Endemic
25. Turpinia malabarica – Neerthani- Ende. SWG,
26. Vateria indica – Undapayin- Vellpayin- Vulnerable – LT – fast growing

Very Low- elevation evergreen riparian species

1. Pongamia pinnata - Vungu
2. Gmelina arborea- Kumbil
3. Machilus macrantha - Kulamavu
4. Terminalia paniculata - Neermaruthu
5. Tetrameles nudiflora - Cheeni
6. Trewia nudiflora – Pambara kumbil
7. Lagerstroemia microcarpa – Vnthekkue
8. Lannea coromandelica - Kalasu
9. Glochidion zeylanicum - Neerola
10. Bombax ceiba – Elavu
11. Bamboosa bambos – Mula

3.4.3. Invasive species Management

Spread of invasive species is one of the major issues to be addressed in the riparian areas of the river affected with August 2018 flood/landslide. Careful management can minimize these negative impacts. Invasive plants belonging to the family Fabaceae can be effectively used for mulching in the agriculture fields to improve the soil fertility and earthworm population, since they have the capacity of nitrogen fixation. Fast and immediate removal of alien plants for a short period does not give proper result. There are three major control measures generally accepted for controlling invasive species i) mechanical removal, Complete burning before flowering and fruiting is suggested. Integrated weed management practices can be implemented. ii) eradication of weeds using chemical, iii) biological control. Expertise is needed to identify resources and the threats to them, and the ability to prioritize by threat, by geographic site or resource being threatened, and by individual plants. The Invasive Species Management Plan should assign a priority score to each invasive species based on its potential impact, current distribution at the preserve, the value of the habitat it invades, and the difficulty of its control.Minimizing the edge habitats that are prone to invasion and Replanting with a diversity of desirable species so that they can shade out invasive species are some of the recomendations.

Aquatic invasive species

The catastrophic floods in August 2018 resulted in the first-ever records of several additional alien species from natural waters revealing the existence of an unregulated, unscientific, mostly illegal and thriving aquaculture and aquarium fisheries sector based on alien species, especially along the riverine floodplains. Only 92 species of ornamental fish are legally allowed to be imported to India, of which 79 are of freshwater origin (Government

of India http://aqcsindia.gov.in/pdf/trade-14.pdf). Of the seven species that were recorded for the first time from the WG subsequent to the floods, many are illegally introduced and farmed for the aquarium pet trade, as they are not listed in the species allowed to be imported to the country. These included large-bodied and high-risk species such as the Arapaima (*Arapaima gigas*) and Alligator gar (*Atractosteus spatula),* top predators capable of feeding on a range of organisms and a serious threat to the endemic fish diversity of the WG region. Most breeding and farming units for aquarium fish in the WG region have no biosecurity systems, and function along the floodplains of major rivers that are vulnerable to annual flooding events

1. An urgent monitoring of the population stocks of non-native fishes and the formulation of a proper regulation strategy to conserve the diverse native fish fauna of the rivers.
2. Strict quarantine and biosecurity measures for any exotic species brought to the state must be ensured and the Department of Fisheries should take stringent action against those growing exotic species illegally.
3. Collection and trade of native rare ornamental fish species from natural waters require regulation. The Sahyadriadenisonii is the most preferred ornamental fish in international trade and its wild stock is getting depleted fast
4. Identification of Inland water body for declaring as Biodiversity Heritage Site. Identification of areas with rare and endemic species for local level strategy and action plan for conservation.
5. Aquaculture farms should be directed to follow standard operational practices and maintaining data.
6. Registration of all aquaculture farms needs to be made mandatory and a regulatory framework for inland aquaculture by State Authorities on the lines of Coastal Aquaculture Authority (CAA) is to be established
7. Certification of environmentally friendly aquaculture systems as a means to promote safe practices in aquaculture should be considered. Best Management Practices (BMPs) / Good Aquaculture Practices (GAPs)/ Code of Conduct for Responsible Fisheries (CCRF)/ Guidelines and Voluntary Guidelines on Sustainable Small Scale Fisheries are to be promoted to ensure sustainability
8. Chloramphenicol, Ciprofloxacin and Furazolidone are the most commonly used antibiotics in aquaculture in the state of Kerala. Most of the antibiotic use is not supervised by any scientific personnel and is generally based on the experience of fellow farmers.The use of drugs and chemicals including antibiotics and pesticides which may influence aquatic species near aquaculture facilities needs to be regulated through suitable mechanism.
    - One of the major negative impact on biodiversity is land-use change associated with aquaculture. The ecological integrity of important natural wetlands has to be conserved and restored and shall not be utilized for Aquaculture.
    - Utilization of ecologically sensitive land areas such as mangroves and wetlands for Aquaculture of exotics needs to be regulated .

- Fish meal made of captured species lead to overexploitation resulting in declining biodiversity. The regulation of seed import is weak and quarantine measures should be followed.
- Species diversification, in Aquaculture has to be considered by focusing on, several native edible species of fish.
- The release of aquaculture waste water to the fresh water sources like rivers should be regulated.
- Frequent exotic eradication campaign may be organized in areas like Periyar for exotics like African cat fish.
- In many places associated with River Achencovil and Pampa news reports of toxic algae were noticed after the flood. Many of the Euglenophycean members and Cyanophycean members can produce toxin. Such forms grow where there is large organic pollution. Detailed research projects shall be unertaken to understand the invasion of exotic aquatic micro-flora from marine environments as well to understand the toxic algal blooms occurring in state. Proper pollution monitoring system should be developed to regularly check the quality of different forms of water.
- Ecotechnological utilization of algae: Many micro-algae present in our water bodies could be used for pollution monitoring and for the production of cosmetic and nutritional products through eco-technology. Many are able to produce essential oils. A detailed research is needed to understand all such forms.

Invasive species Regulatory Agency

- An Invasive species Management Plan should be developed by the local bodies and BMCs which can include identification of priority areas, and control measures using the workforce from MNREGS. The plan shall assign a priority score to each invasive species based on its potential impact, current distribution at the preserve, the value of the habitat it invades, and the difficulty of its control. Expertise is needed to identify resources and the threats to them, and the ability to prioritize by threat, by geographic site or resource being threatened, and by individual plants.
- The spread of invasive species both Floral and faunal should be regulated strictly by forming an exclusive agency for the purpose by KSBB in association with forest and wildlife.
- In order to prevent the unwanted growth of alien plants an online reporting programme can be developed. This should be implemented in co-operation with Panchayath's and Municipalities. Proper monitoring and awareness about these plants to local people, shall help in preventing the spreading of invasive plant species.

3.5. Livelihood

During the survey it is noticed that income to tribal persons decreased significantly due to the after effect of flood. NTFP resource crunch and consequent crisis therefore need to be addressed effectively.

Agencies like Vana Samrakshana Samiti (VSS) can effectively contribute by initiating steps to promote bee keeping, vegetables and spices cultivation, fish farming etc. and such

activities will support livelihood of the people in the area. The activities of tribal welfare society and self-help groups such as kudumbasree are to be rejuvenated further especially for confidence building to initiate small scale vegetable cultivation, bee keeping etc. In Malakapara colony respondents informed that the functioning of Malakkapara Tribal Society was stopped for a long period. Therefore it is recommended that active support from various developmental society is to be insured for collection and selling the gathered NTFPs in the entire study area.

After flood, frequency of wild animal conflict increased possibly due to disturbance and habitat loss of the animals or scarcity of food in their natural habitats. Therefore effective measures to keep away wild animals from the settlements are to be initiated. Electric fencing available in some settlements are of partially damaged condition after flood, and need to be made functional at the earliest. Promoting native fruit plants in the buffer areas of wild life sanctuaries is also recommended to reduce wildlife especially monkeys in the colonies.

To take up the land slide and other calamities in future, it is recommended to provide training in disaster management to the people in this area.

Proper management measures should be adopted for the cultivation of agricultural crops. Promotion of stress resistant native varieties, especially the varieties of rice, sugarcane and banana that can resist floodwater for a few days is recommended. Proper distance should be maintained while planting such crops. Farmers should be properly informed to avoid the spread of diseases after the calamity. The cultivation season should be scientifically selected to avoid the adverse effects of flood, drought etc. Government subsidies and crop insurance should be given to the farmers to overcome large-scale loss.

Peoples Biodiversity registers of plants and animals should be prepared in each Panchayath. This can be used as a ready reference guide which will help the researchers to priotize species for conservation. Special attention can be given to the traditional varieties of that Panchayath based on the information available in the register. The register should be updated periodically through the active participation of BMCs.

- Soil and water profile of the different wards of the Panchayath should be made. Mulching the flood affected soil (Ranni, Kozhencherry and Chengannur) with Gliricidia sepium (spotted Gliricidia; Mal: Cheemakonna) is very effective to improve soil nitrogen content thereby improving micro arthropod density. Mulching insulates the soil helping to provide a buffer from heat and cold temperatures, retains water helping to keep the roots moist, keeps weeds out, prevents soil compaction.
- Soil fertility can be improved by incorporating cover crops that add organic matter to the soil, which leads to improved soil structure and promotes a healthy fertile soil.
- Encourage the growth of soil micro organisms and maintain the soil fertility through their decomposition process.
- Promote the cultivation of nitrogen fixing plants like leguminous plants in the flood affected areas.
- Organic based fertilizer use is beneficial because it supplies micronutrients, and organic components that increase soil moisture retention and reduce leaching of nutrients.

- Organic fertilizers can be used on acid tolerant and those better suited to neutral or alkaline conditions. It can improve the biodiversity and long-term productivity of flood affected soil, and may prove a large depository for excess carbon dioxide.
- Promote the spreading of organic agro-forestry systems with multispecies culture in the flood affected areas to improve soil fertility and multilayer canopy. This may lead to diversity of crops and availability of multilevel nutrient composition in soil by the action of micro arthropods.
- Promote the use of vermicompost, cow dung and slurry in the flood affected areas to improve the density of soil micro arthropods and thereby increasing soil fertility.
- Avoid the overuse of chemical fertilizers in the flood affected areas to reduce over nutrition in the crop sowing season and gradual reduction of soil fertility in the subsequent seasons.
- Advocate the use of organic pesticides like neem decotions and tobacco decotions to reduce pest problems in the field thereby reducing chemical pesticide contamination in soil and strengthen the density of micro arthropod community.
- Mixed cropping improve soil fertility
- Farmers should be given financial support for organic farming which can improve the soil fertility gradually in the flood affected soil.
- Extensive study on the diversity and density of soil microarthropods and other mesofauna is necessary in the flood affected areas to a minimum of 3 years then only improvement of soil fertility and loss of soil fauna diversity can be assessed scientifically.
- Biofertilizers like microbial inoculants which are capable of mobilizing important nutritional elements in the soil from non-usable to usable form through biological processes.
- Consult with a professional agricultural officer once in 6 months after testing soil to discuss about the soil status and health.
- Agriculture department shall Provide planting materials at the correct planting time coinciding with the rainfall.
- Insurance cover for agriculture crops should be made mandatory in flood prone areas for availing government support including free supply of planting material etc.
- All sloped areas which are cultivated should be terraced in a phased manner in every Panchayat. Erosion aiding crops like tapioca should not be permitted to be cultivated on vulnerable slopes.
- In Kuttanad region the study indicates that the area under varshakrishi in Alapuzha and Kottayam is increasing lately and over 45 % of the land area under rice is put to use for varshakrishi in Kuttanad. Although it is recommended to limit the varshakrushi to not more than 30% this is not generally followed reducing the space of flood waters and augmenting the severity of floods. Hence increase in varshakrushi beyond 30% shall not be promoted as Kuttanad polders are different from paddy fields in other areas, owing to its unique role of flood cushioning.
- The incursion of saline water to upstream regions of Thanneermukkom barrage during 2018 prior to the flood indicate that despite closure of the barrage saline incursion beyond permissible levels can only be due to extreme reduction of water level. A minimum seaward environmental flow in the wetland by storage of water in the flood plains shall be maintained The uncultivated Padasekharam in Kuttanad shall be used seasonally as water storage structures during rainy season.

- Structural engineering mechanisms such as spillways and ring bunds around polders or barrage constructed by altering hydrologic regimes cannot be a solution but, such civil structures only create hurdles to smooth flow.
- Polders to be used as seasonal flood water storage systems, fish reproduction protection zones for endemic fishes and water harvesting structures that enable post monsoon seaward flow to hold up salinity ingression.
- The Agriculture Department should take care of the agricultural season, selection of crops and varieties suitable for cultivation according to season and soil profile of the area. More over, they should give proper guidance to the farmers regarding the application of fertilizers, weeding etc. Disease resistant, draught, flood and wind resistant crops should be suggested to the farmers.

3.6. Mangrove restoration

Mangrove awareness

- Public awareness of both the biological and economical importance of natural resources of mangroves and the need for proper management is crucial in order to improve the environmental quality as a whole.
- Informing the local public about the unique features of mangroves, their values, and the potential consequences of their loss is of high importance. For example unique fruit color of Bruguiera cylindrical, true mangrove in Kadalundi Birds Sanctuary.
- Awareness of the ecological links between mangrove ecosystems and resources such as fish is key to winning management support.
- The instillation of a sense of ownership of the resources by the local population and their legal empowerment so that they are able to institute and execute control measures on their resources are also essential components in the process aimed at achieving full community support for the sustainable utilization and management of common resources.

Major recomendations

Mangroves play a significant role in controlling coastal erosion and improving water quality of the area and protect the coastlines from flood, cyclones and tsunami. Mangroves are known to provide shelter, act as nursery grounds and are also habitats for economically important fishes, prawns, crabs and molluscs. The primary aim of a mangrove management strategy should be to maintain the health of the remaining mangrove ecosystems (thereby improving their resilience) and to reduce the rate of mangrove loss. This is often more effective than trying to plant new mangroves and is less expensive than other approaches.

- Kallai mangrove area should be properly managed. The timber deposition from saw mills seriously affects mangroves and indicator species.
- The density of crabs and gastropods as “indicator species” in Mangalvanam Birds Sanctuary are reduced significantly and should be monitored. The indicator species (fishes, carbs and molluscs) were drastically reduced in Kadamakkudy also.
- Accretion of sand in Kadalundi is a serious problem which causes dying of mangroves which finally affects the dependent fauna.

- The emergence of novel microbial families Ignavibacteriae (Iino et al., 2010), in Mangalavanam, Kadalundi and Kallai mangroves and Calditrichaeota (Marshall et al., 2017), Mucoromycota (fungi) in Kadamakkudy mangrove was noticed.
- Introduction of mangroves in open areas of the swamps and ensure facilities for its growth. It will help to reduce the radius of the open areas and such a way we can prevent the expansion of weeds.
- Prevalence of antibiotic resistance genes should be studied in Kadamakkudy region due to extensive aquaculture. Here aquaculture is to be made more ecofriendly, sustainable and productive
- Seasonal studies on the composition of soil microbes and Microbiome of each mangrove plant in relation to microniche is necessary. This will be helpful while introducing mangrove plants in areas like Puthuvypin
- Commercial constructions in the nearby areas of mangrove forests have a detrimental impact on the ecosystem and in long term will impact coastal habitations
- *Control of Invasive Alien Species in Mangrove areas :* The following methods are proposed to control and prevent the invasion and the expansion of the weed plants. Efforts should be focused on preventing their spread from already established areas by:

  a. Restricting the movement of soil and plant parts from infested areas to un-infested areas and

  b. Removing the weeds manually or mechanically (cutting or pulling) before flowering and fruiting and burning them at the site

Establishment of Mangrove nursery

- A temporary 'flooded mangrove nursery' can be established in low intertidal areas, which are regularly flooded by tidal waters. This kind of nursery will provide seedlings for one or two-year planting projects, and requires less effort in terms of setup and maintenance.
- Identification of appropriate sites for mangrove cultivation can be done based on soil stability, flooding regime, elevation, extent of pollution. Relatively flat land; closeness to fresh water sources; easy transportation access; good drainage (not waterlogged) and close proximity to planting site are some of the criteria. For eg : Adjoining areas of Perumbalam and Pallipuram Island can be selected as the site for same.
- The most important factor to be considered when assessing a site for rehabilitation is selecting the most appropriate species of plant. For example, Puthuvyppin. (*Avicennia marina*); Kadamakkudy(S*onneratia caseorlaris*).
- Quality of the planting material is to be ensured
- Adoption of an appropriate planting technique
- Reduction of predator pressure
- After-care practices
- Mechanisms to obtain local community participation and support for restoration

3.7. Implementation and inter departmental collaboration

The activities of almost all government departments in the state are and linked with the river basin management in one way or other. Integrated River Basin Management (IRBM) requires linkage between some of the activities of these departments for a proper implementation of a management plan as mentioned in the framework suggested. The major institutions directly linked with river basin management projects are listed below:

Suggested Policy recommendations:

Local Policy recommendations : The BMCs (Local Bodies) has to play an important role in the river restoration activities. The local bodies, both urban and rural, have to clearly define their roles and responsibilities of the elected representatives and staff to involve in the activities. There should be a local level policy to involve the grass root level people to participate in the river rejuvenation activities right from the base data collection. The gram sabhas has to be strengthened through this policy initiative. As the rivers are the cultural centers of the community, the role of religious leaders also to be considered.

State level Policy recommendations: For the successful implementation of the activities for river rejuvenation in an integrated manner, there is a need for State level policies for river rejuvenation. An autonomous body for coordinating all activities related to river basin management has to be formed. This may be a river basin management authority with full powers of coordinating the activities of different agencies/departments involved in river management in Kerala by pooling all the available funds to the independent body. The main objective should be to ensure the ecological/ environmental flow in all the rivers.

Table 19 Major Institutions - River basin managment.

Name of Department / Institution	Major Activities to be Linked For IRBM
Irrigation (http://www.irrigation.kerala.gov.in/) Kerala Water Authority (https://kwa.kerala.gov.in/) Kerala Rural Water Supply and Sanitation Agency (https://jalanidhi.kerala.gov.in/) Communication and Capacity Development Unit (CCDU)	Rural water supply Awareness creation
Department of Agriculture Development & Farmers' Welfare (www.keralaagriculture.gov.in) and various institutions under it like VFPCK, Horticorp etc.	Paddy field conservation and management, Promoting organic farming and marketing products
Department of Forest and Wildlife http://www.forest.kerala.gov.in/	Protection of natural areas including Mangroves Afforestation of degraded areas Involvement of Vana Samrakshana Samithi/ Eco development Societies Supply of planting materials (Social Forestry)
Department of Fisheries (www.fisheries.kerala.gov.in) and Various autonomous institutions under it like: Kerala State Cooperative Federation for Fisheries development Ltd (Matsyafed) Agency for Development of Aquaculture, Kerala (ADAK) State Fisheries Resource Management Society (FIRMA)	Promoting livelihood activities through aquaculture and related activities Establishing waste management facilitates in fish markets (KSCADC) Training and capacity building in fishery resource management (NIFAM)

Kerala State Coastal Area Development Corporation (KSCADC) National Institute of Fisheries Administration and Management (NIFAM) Kerala Aquaventures international limited (KAVIL)	
Department of Revenue	Identification of encroached areas and taking it back Restriction to Sand/Clay/Rock mining based on scientific studies Disaster Management
Suchitwa Mission (https://sanitation.kerala.gov.in)	Health and Sanitation Solid and Liquid Waste Management
Department of tourism www.keralatourism.gov.in	Responsible Tourism initiatives Developing tourism infrastructure
Department of Cultural Affairs (http://www.keralaculture.org/)	Conservation of tangible and intangible heritage associated with rivers
Haritha Keralam Mission	River rejuventation

AGRODIVERSITY OF WAYANAD

The study identified the agricultural practices and crop varieties that have shown high degree of resilience to flood and heavy rainfall. The study recorded 46 crops and 432 varieties from Wayanad. Among them paddy, pepper, coffee, fruit trees and dioscorea show higher degree of survival. Banana, areca nut, ginger, yam varieties show high degree of vulnerability to flood and heavy rain. Among the crops pepper and banana in the lower elevation are seen as vulnerable while these crops which show more survival tendency occur in the higher elevations (above 850 msl). The paddy varieties such as Valichoori, Thonnuram Thondi, Thondi, Palthondi, KudakuVeliyan and Veliyan show higher rate of survival. There is also a trend noticed among the farmers from the higher elevation wetlands of sowing Kalladiyaryan after the flood. The newly introduced traditional paddy varieties from other parts of the country like Kakisaali and Black Paddy also survived the flood. The pepper varieties like Aibiriyan, Thirimuriyan, Wayanadan bolt and Kurukkachi are survived varieties. A total of 54 varieties of dioscorea were reported to be cultivated at Wayanad. Out of which 45 were traditional and 9 were improved varieties. This study recorded 97 varieties of Rice including 11 high yielding varieties of rice under cultivation in the year 2018. Apart from that, 157 varieties of tubers, 35 varieties of pepper, 23 varieties of banana and varieties of vegetables and trees were recorded. The mapping of crop diversity and varieties were conducted using a mobile application developed in a Geo-spatial Platform.

The case studies show that farm management including soil and water management is also important in withstanding adverse climate. The percentage of loss in crop and production in the farmlands of zero budget farmers is only 12% while it is 46% in other cases. At the same time 87% of farmers who are adapting to the formal system of agriculture are suffering from crop loss due to the extreme climate events. The results showcase the need for local level conservation of diverse crop varieties to withstand the climatic fluctuations. The formal systems and structures which decide on agriculture development should be adaptive to include the local innovations and knowledge from farm level.

Table 20 The number of crop varieties listed for the study and the number of varieties mapped

No.	Name	Crop group	Number of Varieties listed	Number of Varieties mapped
1.	Rice	Cereals	106	97
2.	Banana	Banana	18	18
3.	Coconut	Coconut	4	4
4.	Areca nut	Areca nut	3	3
5.	Coffee	Coffee	3	3
6.	Pepper	Spices	20	19
7.	Spices	Spices	6	6
8.	Colocasia	Tubers and roots	6	6
9.	Dioscorea	Tubers and roots	29	25
10.	Arrowroot	Tubers and roots	3	3
11.	Tapioka	Tubers and roots	6	4
12.	Yarm	Tubers and roots	4	5
13.	Other tubers	Tubers and roots	3	5
14.	Turmeric	Tubers and roots	18	13
15.	Ginger	Tubers and roots	12	3
16.	Citrus	Trees	13	13
17.	Mango	Trees	47	31
18.	Common Trees	Trees	41	40
19.	Fruit Trees	Trees	15	15
20.	Common Leafy greens	Leafy greens	6	7
21.	Amaranths	Leafy greens	6	6
22.	Chaow Chaow	Vegetables	3	3
23.	Bottle Gourd	Vegetables	3	3
24.	Ivy Gourd	Vegetables	3	3
25.	Ash Gourd	Vegetables	5	5
26.	Pumpkin	Vegetables	6	6
27.	Bitter Gourd	Vegetables	4	4
28.	Chilly	Vegetables	5	5
29.	Snake Gourd	Vegetables	3	3
30.	Pappaya	Vegetables	3	4
31.	Sponge Gourd	Vegetables	2	2
32.	Bringal	Vegetables	8	8
33.	Cucumber	Vegetables	5	5
34.	Ladies finger/ Okra	Vegetables	4	4
35.	Legumes	Legumes	50	36
	Total			

Table 21 Climate Resilient Crop Varieties

Sl. No	Crop	The Most Climate Resilient Varieties
1	Rice	Thonnooram Thondi, Mannu Veliyan, Mullan Kaima, Chenbavu, Thavalakkannan, Njavara, Palthondi, Chennel Thondi, Gandhakasala, Malli Kuruva, Ramli and Kakisali.
2	Pepper	Ayimberiyan, Kalluvalli, Karimkotta, Karimunda, Thirumuriyan, Thulamundi, Valankotta, Wayanadan Bolt and Vellanamban
3	Banana	Charakadali
4	Dioscoria	Vella kachil, Neela kkachil, Kayyalapoliyan
5	Turmeric	Wayanadan, Kanthi

1. The mobile application developed for this study can be used as a platform for monitoring agrobiodiversity across the state. The data can collected in each season and that can used for further planning of agriculture.
2. The action points can be of three fold one conservation action of vulnerable and resilient varieties, two adapting the resilient varieties and crops to the active farming through projects and programmes and three continuous research and generation of information regarding climate adaptation of crop plants. The conservation and agricultural development programmes have to be revised as part of this cycle of information generation and use and planning.
3. Many varieties are cultivated by minimal number of farmers so custodian farmer directory has to be prepared by each BMC.
4. Custodian farmers should be recognized and rewarded at local and state level. They should be a custodian farmer network to facilitate and coordinate their activities.
5. Panchayath BMC should come up with community seedbanks as live repository of all agricultural genetic resourses present in their jurisdiction.
6. The transfer of the knowledge generated to agricultural department and creation of a platform for active dialogue between the farmers, agricultural officers, planners and research institutions is vital in planning for future.
7. Agricultural officers should be actively involved in the conservation activities of BMCs at each Panchayath.
8. There should be a mechanism to produce seeds and planting materials of crop varieties that are cultivated in large scale at local level.
9. Systematic monitoring of climate responses by each crop and variety should be part of agricultural development programmes.

CONCLUSIONS

The experience from the flood/landslide and the acute water scarcity in many parts of State in summer months during the past few years have provided an exceptional opportunity to rethink about our approach to the River management. The Government is now thinking more holistically about the State's development after flood. Normally, the river management activities in Kerala is being undertaken mainly by various departments such as Irrigation, Agriculture, Kerala Water Authority, Kerala State Electricity Board etc., because of the focus of development in these sectors. The activities were heavily dominated by civil construction. Although generally effective in meeting the objectives, this single-discipline approach ignored other ecological values of rivers.

The state has devolved a large number of development functions to local bodies and has seriously attempted to operationalise the constitutional provisions in letter and spirit. In this circumstances, planning and implementation of any activities for river basin management will be easy through the local bodies (BMCs) with active involvement of KSBB and other line departments functioning in the State. While implementing mega projects, tourism and other developmental activities the biodiversity impact assessment for that particular area should be carried out and the ecosystem value in turn with the economic outcome should be compared.

While implementing a project the collective effort of all the Departments related with the ecosystems including Agriculture, Forest, Fisheries, and Tourism shall be ensured. This helps in the integrated management and planning, since each of such Departments have a direct responsibility in the ecosystem management.

BMC level meetings should be conducted in each of the affected Panchayaths and they should be provided a small booklet in Malayalam on the findings of the studies. Awareness should be given to BMC members for the proper implementation of the project findings for the long term and short-term restoration of the lost biodiversity.

District Panchayath, GramaPanchayath and biodiversity monitoring committee of each of the affected Panchayaths and Municipalities, Agricultural Department, Fisheries Department, Forest department should be included in implementing and monitoring the strategies.

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..

Table 22 Species prioritized for riparian afforestation programme										
Sl. No.	Botanical name	Local name	IUCN Status	Ende mism	Med. Value	Other Uses	Near Water Suitability	Distribution		Prior. Score
								River	Region	
HIGH PRIORITY SPECIES										
TREES										
1	*Hopea glabra* Wight & Arn.	Puzhapongu	EN	WG		River bank Protection		PR	HL	35
2	*Syzygium chavaran* (Bourd.) Gamble	Chavaran	EN	PI		River bank Protection		CH	HL	33
3	*Cinnamomum riparium* Gamble	Aattuvayana	VU	SWG		River bank protection		PR,CH	ML,HL	32
4	*Cullenia exarillata* Robyns	Vediplavu, Karani		SWG	YES	River bank Protection		CH, BP	HL	32
5	*Garcinia wightii* Anders.	Attukaruka, Kolivala	VU	SWG		River bankProtection, Animal food		PM	HL	32
6	*Holigarna arnottiana* Hook.f.	Cheru		SWG	YES	River bank protection		All	LL,ML,HL	32
7	*Hopea parviflora* Bedd.	Irumpakam		SWG	YES	River bank protection		PM, PR, CH	ML,HL	32
8	*Ochreinauclea missionis* (Wall. ex G. Don) Ridsd.	Aattuvanchi, Neervanchi	VU	SWG		River bank protection		All	LL,ML, HL	32
9	*Pterospermum reticulatum* Wight & Arn.	Malayooram	VU	SWG		River bank Protection		PR	HL	32
10	*Strychnos potatorum* L.f.	Thettamaram		SWG	YES	River bank Protection		PM	HL	32
11	*Syzygium cumini* (L.) Skeels var. cumini; Manilal & Sivar.	Njaval		SWG	YES	River bank Protection		All	LL,ML, HL	32
12	*Syzygium occidentale* (Bourd.) Gandhi	Aattuchamba	VU	SWG		River bank protection		PM, PR,CH	HL	32
13	*Vepris bilocularis* (Wight & Arn.) Engl.	Moothasseri		SWG	YES	River bank Protection		PM	HL	32
14	*Barringtonia racemosa* (L.) Spreng.	Samudracham-pa, Samudrakai			YES	River bank protection	YES	PM, PR,BP	LL,ML	30
15	*Calophyllum inophyllum* L.	Kattupunna, Malampunna, Punna			YES	River bank Protection	YES	PM, PR,CH	LL,ML	30
16	*Cerbera odollam* Gaertn.	Chanthankai, Othallam			YES	River bank Protection	YES	PM, PR	LL	30
17	*Crataeva magna* (Lour.) DC.	Neermathalam			YES	River bank protection	YES	All	LL,ML,HL	30

18	*Garcinia gummi-gutta* (L.) Roxb.	Gorakappuli, Kudampuli, Marapuli			YES	River bankProtection, Animal food	YES	PM, PR,CH	LL,ML,HL	30
19	*Lagerstroemia speciosa* (L.) Pers.	Manimaruthu, Poomaruthu			YES	River bank protection	YES	All	LL,ML, HL	30
20	*Neolamarckia cadamba* (Roxb.) Bosser	Aattuthekku, Vellakadambu			YES	River bank protection	YES	PM, PR, CH	ML,HL	30
21	*Salix tetrasperma* Roxb.	Puzhapanji, Vachi			YES	River bankProtection, Fish breeding	YES	PM, PR, CH	HL	30
22	*Vitex leucoxylon* L.f.	Aattunochi, Neernochi			YES	River bankProtection, Fish breeding	YES	PM, PR, CH	HL	30
23	*Arenga wightii* Griff.	Alathilthenga, Malanthengu, Kattuthengu	VU	WG		River bankProtection, Fish breeding		PM, PR, CH	HL	30
24	*Casearia wynadensis* Bedd.	Karikunnan	VU	WG		River bank Protection		BP	HL	30
25	*Cinnamomum sulphuratum* Nees	Kattukaruva	VU	WG		River bank Protection		CH	HL	30
26	*Garcinia indica* (Thouars) Choisy	Punampuli	VU	WG		River bankProtection, Animal food		CH	ML,HL	30
27	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Marotti	VU	WG		River bank Protection		All	ML,HL	30
28	*Lagerstroemia microcarpa* Wight	Vellilavu		WG	YES	River bank protection		PM, PR,CH	HL	30
29	*Myristica malabarica* Lam.	Pathripoo	VU	WG		River bank Protection		CH	HL	30
30	*Poeciloneuron indicum* Bedd.	Poothamkolly		WG	YES	River bank Protection		CH	HL	30
31	*Xanthophyllum arnottianum* Wight	Madakka, Mottal		WG	YES	River bank Protection		PM, PR, CH	HL	30
32	*Neonauclea purpurea* (Roxb.) Merr.	Manjanirk-adambu		PI		River bank protection	YES	PR	HL	28
33	*Chionanthus mala-elengi* (Dennst.) *P.S.Green*	Mala-elengi, Perumbal		PI	YES	River bank Protection		All	ML,HL	28
34	*Diospyros paniculata* Dalzell	Karivela, Ilak-katta	VU	PI		River bank Protection		PM	HL	28
35	*Ehretia canarensis* (Clarke) Gamble	Chavandi		PI	YES	River bank Protection		PR	HL	28

SHRUBS										
36	*Ixora johnsonii* Hook.f.		CR	Kerala				PM, PR	HL	35
37	*Orophea uniflora* Hook. f. & Thoms.		VU	SWG		River bank Protection		CH	HL	32
38	*Saprosma foetens* (Wight) K. Schum.	Theettanari		SWG	YES	River bank Protection		PR	HL	32
39	*Homonoia riparia* Lour.	Neervanchi, Kadallari, Puzhavanchi			YES	River bank protection	YES	All	LL,ML,HL	30
40	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	Eera, Kolanchi, Oodal		WG		River bank protection	YES	All	HL	30
41	*Pandanus odorifer* (Forssk.) Kuntze	Pookaitha, Thazhampoo			YES	Breeding fishes Local livelihoodBank protection	YES	PM, PR, CH	ML,HL	30
42	*Kandelia candel* (L.) Druce	Cherukandal			YES	River bankProtection, Fish breeding	YES (Mangrove)	PR	ML	30
43	*Rhizophora mucronata* Poir.	Panachikandal			YES	River bankProtection, Fish breeding	YES(Mangrove)	PR	LL	30
44	*Pandanus furcatus* Roxb.	Kaitha		PI	YES	Breeding fishes Local livelihoodBank protection		CH, BP	ML	28
45	*Pandanus kaida* Kurz	Kaitha		PI	YES	Breeding fishes Local livelihoodBank protection		PM	ML	28
CLIMBERS										
46	*Salacia beddomei* Gamble	Korantivalli	VU	SWG		River bank protection		CH	HL	32
47	*Moullava spicata* (Dalz.) Nicolson	Kattukazhanji Kakka-kalinga-valli		WG	YES	River bank Protection		PR	HL	30
HERBS										
48	*Rotala malampuzhensis* R.V. Nair ex Cook			Kerala		Water Purification	YES	CH	ML	35
49	*Anaphalis wightiana* DC.		VU	SWG			YES	PM	HL	32
50	*Aponogeton appendiculatus* van Bruggen			SWG		Water Purification	YES	PM	HL	32
51	*Lagenandra nairii* Ramamurthy & Rajan			Kerala		Water Purification	YES	CH	HL	32

52	*Lindernia tamilnadensis* M.G.Prasad & Sunojk.			SWG		Water Purification	YES	BP	ML	32
53	*Colocasia esculenta* (L.) Schott	Chembu			YES	Water Purification	YES	All	LL,ML,HL	30
54	*Eriocaulon pectinatum* Ruhland		VU	WG			YES	BP	ML	30
55	*Hydrilla verticillata* (L.f.) Royle				YES	Water Purification	YES	PM, PR,CH	LL	30
56	*Hygrophila schulli* (Buch.-Ham.) M. R. & S. M. Almeida	Neermulli, Vayalchulli			YES	Water Purification	YES	All	LL,ML	30
57	*Lagenandra ovata* (L.) Thw.	Aandavazha Karin-pola			YES	Water Purification	YES	PM, PR	LL,ML,HL	30
58	*Limnophila aromatica* (Lam.) Merr.	Manganari			YES	Water Purification	YES	PR	ML	30
59	*Monochoria vaginalis* (Burm. f.) Presl.	Kakkapola			YES	Water Purification	YES	All	LL,ML	30
60	*Nelumbo nucifera* Gaertn.	Thamara			YES	Water Purification,LED	YES	BP	ML	30
61	*Nymphaea nouchali* Burm.f	Poothali, Vel-lambal			YES	Water Purification	YES	PM	LL,ML	30
62	*Nymphoides hydrophylla* (Lour.) O. Ktze.	Neythelambal			YES	Water Purification	YES	PM	LL,ML	30
63	*Ottelia alismoides* (L.) Pers.				YES	Water Purification	YES	PM	LL	30
64	*Phragmites karka* (Retz.) Trin. ex Steud.	Vezhamkole Chora pullu			YES	River bankProtection, Water purification	YES	PM, PR, CH	LL,ML,HL	30
65	*Rotala macrandra* Koehne			WG		Water Purification	YES	CH	ML	30
66	*Rotula aquatica* Lour.	Kallorvanchi			YES	River bank protection	YES	All	ML,HL	30
67	*Saccharum spontaneum* L.	Njangana, Chottapullu, Kurikilkarimbu			YES	River bankProtection, Water purification	YES	All	LL,ML,HL	30
68	*Entada rheedei* Spreng.	Kakkavalli, Kuk-kumkai, Paran-da-ka Valli			YES	River bank protection	YES	PM, PR, CH	LL,ML,HL	30
69	*Lindernia oppositifolia* (Retz.) Mukerjee			PI		Water Purification	YES	PR	ML	28
MEDIUM PRIORITY SPECIES										
TREES										
1	*Diospyros crumenata* Thw.	Karimaram , Karimbudan	EN			River bank Protection		CH	HL	25
2	*Actinodaphne wightiana* (Kuntze) Noltie	Kambilivirin-ji,Mala virinji, Nyaram		SWG		River bank protection		PM	HL	22

3	*Artocarpus hirsutus* Lam.	Anjili, Ayani		SWG		Food-Man,animals		All	LL,ML,HL	22
4	*Calophyllum austroindicum* Kosterm. ex Stevens			SWG		River bank protection		CH	HL	22
5	*Cinnamomum malabatrum* (Burm.f.) *J.Presl*	Ilavangam, Vayana,Idana		SWG		River bank Protection		All	LL,ML,HL	22
6	*Croton malabaricus* Bedd.	Umithinnikodi		SWG		River bank protection		PM	HL	22
7	*Diospyros sulcata* Bourd.	Kari		SWG		River bank Protection		PM	HL	22
8	*Drypetes venusta* (Wight) Pax & Hoffm.	Chootta		SWG		River bank Protection		PR	HL	22
9	*Ficus dalhousiae* Miq.	Kallal		SWG		River bankProtection, Animal food		PR,CH	HL	22
10	*Litsea laevigata* (Nees) Gamble			SWG		River bank protection		PR	HL	22
11	*Memecylon depressum* Benth. ex Triana	Kaikkathetti		SWG		River bank protection		BP	ML	22
12	*Otonephelium stipulaceum* (Bedd.) Radlk.	Poripoovam, Paviri mulei		SWG		River bank Protection		PM	HL	22
13	*Polyalthia fragrans* (Dalzell) Hook.f. &Thomson	Nedunar, Chel-la, Kodangi		SWG		River bank Protection		PM, PR,CH	HL	22
14	*Pterospermum rubiginosum* Heyne ex Wight & Arn.	Chittilaplavu		SWG	YES			PR	HL	22
15	*Semecarpus travancorica* Bedd.	Avukkarum		SWG		River bank Protection		PM	ML,HL	22
16	*Solenocarpus indicus* Wight & Arn.	Kattambazham		SWG		River bank Protection		PR	HL	22
17	*Symplocos macrophylla* Wall. ex A. DC	Malankuruvi		SWG		River bank Protection		CH	HL	22
18	*Syzygium laetum* (Buch.-Ham.) Gandhi	Kattuchamba Manjachamba		SWG		River bank protection		PR,CH	HL	22
19	*Syzygium salicifolium* (Wight) J.Graham	Vallamanchi		SWG		River bank protection		PM	HL	22
20	*Tabernaemontana alternifolia* L.	Kundalapala, Koonampala, Kunninpala		SWG	YES			PM, PR,CH	ML,HL	22
21	*Willisia selaginoides* (Bedd.) Warming ex Willis		VU	SWG				PR	HL	22
22	*Adenanthera pavonina* L.	Manchadi			YES	River bank protection		PM, PR,CH	LL, ML	20
23	*Aglaia barberi* Gamble	Chuvannaakil, Karakil		WG		River bank protection		CH	HL	20
24	*Aglaia lawii* (Wight) Saldanha	Vellacheelam				River bank protection		CH	HL	10

25	*Agrostistachys borneensis* Becc.	Mulimpala				River bank protection		CH	HL	10
26	*Alangium salviifolium* (L. f.) Wang.	Ankolam			YES	River bank protection		All	ML,HL	20
27	*Alstonia scholaris* (L.) R.Br.	Ezhilampala, Mangalapala, Yakshipala			YES	River bank protection		All	LL,ML,HL	20
28	*Antiaris toxicaria* Lesch.	Arayanjili				River bank protection		PR	HL	10
29	*Aporosa acuminata* Thw.	Neervetti Swarnavetti				River bank protection		PM	HL	10
30	*Archidendron bigeminum* (L.) I.C.Nielsen	Kattukonna, Pannivaka, Muthakolap-pan, Varikri,				River bank protection		PM	HL	10
31	*Avicennia officinalis* L.	Uppatti				River bank protection	YES (Man-grove)	PR,CH	LL	20
32	*Barringtonia acutangula* (L.) Gaertn.	Aattupezhu, Neerpezhu				River bank protection	YES	All	LL,ML	20
33	*Bischofia javanica* Blume	Cholavenga, Mlachethayan, Neeli, Thirippu				River bank protection		PM, PR,CH	HL	10
34	*Bridelia retusa* (L.) A.Juss.	Mullumaruthu, Mulluvenga			YES	River bank protection		All	ML,HL	20
35	*Bruguiera cylindrica* (L.) Blume	Kuttikandal				River bankprotection, Fish Breeding	YES (Man-grove)	PR	LL	20
36	*Bruguiera gymnorrhiza* (L.) Savi.	Karakandal				River bankprotection, Fish Breeding	YES (Man-grove)	PR	LL	20
37	*Buchanania lanzan* Spreng.	Padacheru				River bank protection		PR	ML,HL	10
38	*Butea monosperma* (Lam.) Taub.	Chamatha Plasu			YES	River bank protection		PM, PR,BP	ML,HL	20
39	*Calophyllum calaba* L.	Aattupunna, Manjapunna,		WG		River bank protection		PM, PR,CH	ML,HL	20
40	*Calophyllum polyanthum* Wall. ex Choisy	Malampunna Kattupunna				River bank protection		CH	HL	10
41	*Cinnamomum verum* Presl.	Karuva				River bank protection		PM, PR,BP	ML,HL	10
42	*Dendrocalamus strictus* (Roxb.) Nees	Illi, Mula			YES	River bank protection		PM	ML,HL	20

43	*Dimocarpus longan Lour.*	Chempoovam, Chempunna, Poripunna			YES	River bank Protection		PM, PR,CH	HL,ML	20
44	*Diospyros buxifolia* (Blume) Hiern	Elichevian, Malamuringa				River bank protection		PM, PR,CH	LL,ML, HL	10
45	*Diospyros peregrina* (Gaertn.) Gurke	Panachi, Vananji				River bank protection		PM	HL	10
46	*Elaeocarpus serratus* L.	Bhadraksham, Kara,Karamavu			YES	River bank Protection		PM, PR,CH	ML,HL	20
47	*Elaeocarpus tuberculatus* Roxb.	Kara, Kodavasi, Mukkanni, Thodayan, Vellathanni				River bank protection	YES	PM, PR,CH	HL	20
48	*Elaeocarpus variabilis* Zmarzty	Kattakara, Kotlampazhamaram		WG		River bank Protection		CH	HL	20
49	*Eugenia mooniana* Wight					River bank protection		PM	HL	10
50	*Excoecaria agallocha* L.	Kannampotti			YES	River bank protection		PR	LL	20
51	*Falconeria insignis* Royle	Kannampotti			YES	River bank protection (Rocky areas)		PR	HL	20
52	*Ficus amplissima* J. E. Smith					River bankProtection, Animal food		CH	HL	10
53	*Ficus arnottiana* (Miq.) Miq.	Kallal, Kallarayal				River bankProtection, Animal food		PM, PR	HL	10
54	*Ficus beddomei* King	Chela, Thavittal		WG		River bank protection		PM, PR	ML,HL	20
55	*Ficus benghalensis* L.	Peral, Vadavriksham			YES	River bankProtection, Animal food		All	LL,ML,HL	20
56	*Ficus benjamina* L. ssp. benjamina L.	Jili, Vellal				River bank protection		CH	HL	10
57	*Ficus benjamina* L. ssp. comosa (Roxb.) Panigrahi & Murti					River bank protection		CH	HL	10
58	*Ficus callosa* Willd.					River bank protection		PM, PR	HL	10
59	*Ficus exasperata* Vahl	Parakam, Therakam				River bank protection Animal food		All	LL,ML,HL	10
60	*Ficus hispida* L.f.	Erumanakku, Kattathi, Parakam				River bankProtection, Animal food		All	LL,ML,HL	10

61	*Ficus microcarpa* L. f.	Kallithi			YES	River bankProtection, Animal food		PR,CH	HL	20
62	*Ficus racemosa* L.	Atthi			YES	River bankProtection, Animal food		All	LL,ML,HL	20
63	*Ficus tinctoria* subsp. gibbosa (Blume) *Corner*	Ithimottu				River bank protection		PM, PR,CH	HL	10
64	*Ficus tsjakela* Burm.f.	Chela, Kara				River bank protection		PM, PR	HL	10
65	*Garcinia morella* (Gaertn.) Desv.	Chigiri, Daram-ba			YES	River bankProtection, Animal food		PR,CH	HL	20
66	*Garuga pinnata* Roxb.	Annakkara, Eechakkara, Karuvembu			YES	River bank Protection		BP	ML	20
67	*Gordonia obtusa* Wall.ex Wight & Arn.	Karikkova, Kattukarana		WG	YES			PR	HL	20
68	*Grewia tiliifolia* Vahl	Chadachi			YES	River bank Protection		All	HL	20
69	*Gymnacranthera farquhariana* (Hook.f. & Thoms.) Warb.	Undappayin				River bank protection		CH	HL	10
70	*Haldina cordifolia* (Roxb.) Ridsd.	Manjakadamp			YES	River bank Protection		PM, PR,CH	HL	20
71	*Homalium zeylanicum* (Gard.) Benth.	Kaluvaluka Manthalaukhi				River bank protection		CH	HL	10
72	*Hydnocarpus alpina* Wt.	Kattumarotti				River bank protection		PM	ML,HL	10
73	*Hymenodictyon obovatum* Wall.	Malamkalli		WG		River bank Protection		PR	HL	20
74	*Knema attenuata* (Hook. f. & Thoms.) Warb.	Chorapali		WG		River bank Protection		PM, PR,CH	HL	20
75	*Lannea coromandelica* (Houtt.) Merr	Uthi, Kalayam, Karas,Karayam, Odiamaram			YES	River bank protection		PM, PR,CH	LL,ML	20
76	*Litsea floribunda* Gamble	Pattuthali		WG		River bank protection		PM	HL	20
77	*Litsea keralana* Kosterm			WG		River bank protection		PM	HL	20
78	*Lophopetalum* wightianum Arn.	Venkotta				River bank protection		PR,CH	HL	10
79	*Madhuca neriifolia* (Moon) H.J.Lam	Aattu-ilippa, Neerilippa, Wallangi				River bank protection, Staple food for Malabar gaint squirel	YES	PM, PR,CH	HL	20

80	*Maesa indica* (Roxb.) A.DC.	Kireethi, Kattu-vizhal,Vannathi			YES	River bank protection		PM	HL	20
81	*Mallotus philippensis* (Lam.) Müll.Arg.	Chenkolli, Kurangumanjal, Noormaram			YES	River bank protection		All	ML,HL	20
82	*Mallotus tetracoccus* (Roxb.) Kurz	Adukanni, Pori-vatta Vattakumbil				River bank protection		PM, PR	ML,HL	10
83	*Mangifera indica* L.	Mavu			YES	River bank protection		All	LL,ML,HL	20
84	*Meiogyne pannosa* (Dalz.) Sinclair	Panthalmaram		WG		River bank protection		PR,CH	HL	20
85	*Melicope lunu-ankenda* (Gaertn.) T.G.Hartley	Kambili,Kanala, Kattuchem-bakam, Na-sakam			YES	River bank protection		PM, PR,CH	ML,HL	20
86	*Mesua ferrea* L. var. ferrea; Hook. f.	Nanku, Churuli			YES	River bank protection		CH	HL	20
87	*Mimusops elengi* L.	Elenji, Mukura, Bakulam			YES	River bank protection		PM	ML,HL	20
88	*Mitragyna parvifolia* (Roxb.) Korth.	Poochakadam-bu, Rosekada mbu			YES	River bank protection		PM, PR	ML,HL	20
89	*Morinda citrifolia* L.	Cheruman-janathi, Kattapitalavam			YES	River bank protection		PM, PR	ML	20
90	*Myristica beddomei* King	Chithirapoovu, Pathiripoovu				River bank protection		PM	ML	10
91	*Neolitsea cassia* (L.) Kosterm.	Venkana Vellakodala				River bank protection		CH	HL	10
92	*Nothopegia racemosa* (Dalz.) Ramam	Naicheru, Cholacheru		WG		River bank protection		PR	HL	20
93	*Orophea erythrocarpa* Bedd.					River bank protection		CH	HL	10
94	*Oroxylum indicum* (L.) Kurz	Palakapayyani, Payyazhantha			YES	River bank Protection		PM	ML	20
95	*Paracroton pendulus* (Hassk.) Miq. ssp. zeylanicus (Thw.) Balakr. & Chakrab.	Modakam Modha				Breeding fishes, Local livelihood, River bank protection		CH	HL	10

96	*Persea macrantha* (Nees) Kosterm.	Kulamvu,Kulir-mavu, Uramavu, Ooravu			YES	River bank protection		PM, PR,CH	HL	20
97	*Polyalthia coffeoides* (Thw. ex Hook. f. & Thoms.) Hook. f. & Thoms.	Nedunar				River bank protection		PR	HL	10
98	*Pongamia pinnata* (L.) Pierre	Pungu, Ungu, Ponnam			YES	River bankProtection, Fish breeding		All	LL,ML,HL	20
99	*Pterocarpus marsupium* Roxb.	Venga			YES	River bank Protection		PM, PR,CH	ML,HL	20
100	*Santalum album* L.	Chandanam	VU		YES			BP	ML	20
101	*Sapindus trifoliatus* L.	Soainkaimaram Uruvangi			YES	River bank Protection		CH	HL	20
102	*Saraca asoca* (Roxb.) de Wilde		VU		YES			CH	ML	20
103	*Schefflera racemosa* (Wight) Harms	Ettilamaram		WG		River bank Protection		PR	HL	20
104	*Schleichera oleosa* (Lour.) Merr.	Dhoothalam, Poovanam, Poovam			YES	River bank Protection		PM, PR,CH	ML,HL	20
105	*Spondias pinnata* (L.f.) Kurz.	Ambazham			YES	River bank Protection		PM, PR, CH	HL	20
106	*Stereospermum colais* (Buch.-Ham. ex Dillw.) Mabb.	Poopathiri, Karingazha			YES	River bank Protection		PR,CH	HL	20
107	*Streblus asper* Lour.	Dindumaram Paravamaram Shangkodarik-sham			YES	River bank Protection		PM	ML	20
108	*Strychnos nux-vomica* L.	Kangnalam, Kanjiram			YES	River bank Protection		All	ML	20
109	*Symplocos cochinchinensis* (Lour.) Moore ssp. laurina (Retz.) Nooteb.	Pachotti, Kampilivetti			YES	River bank Protection		PR	HL	20
110	*Syzygium calophyllifolium* Walp.				YES	River bank protection		BP	HL	20
111	*Terminalia elliptica* Willd.	Karimaruth			YES	River bank protection		PR,CH	HL	20
112	*Tetrameles nudiflora* R.Br.	Cheeni, Vel-lapasa				River bank protection		PM, PR,CH	HL	10
113	*Thespesia populnea* (L.) Sol. ex Corrêa	Cheelanthi, Pooparuthi, Poovarasu			YES	River bank protection		PM, PR,CH	LL,ML	20

114	*Trewia nudiflora* L.	Ammanaka, Malamkumbil, Naikumbil			YES	River bank protection		All	LL,ML,HL	20
115	*Viburnum punctatum* Buch.-Ham. ex D. Don	Konnakara			YES	River bank Protection		PR	HL	20
SHRUBS										
116	*Tarenna monosperma* (Wight & Arn.) *N.P.Balakr.*	Kattukappi	EN	SWG				PM	HL	27
117	*Orophea sivarajanii* Sasidh			Kerala		River bank Protection		CH	HL	25
118	*Pandanus canaranus* Warb.	Thazhakaitha			YES	Breeding fishes, Local livelihood, River bank protection		PM, PR	ML,HL	10
119	*Pandanus palakkadensis* Nadaf			Kerala		Breeding fishes, Local livelihood, River bank protection		BP	ML	25
120	*Phaeanthus malabaricus* Bedd.	Kunukipanal		Kerala		River bank Protection		CH	HL	25
121	*Ochlandra travancorica* (Bedd.) Gamble	Eetta, Karetta, Oda,Vezhal		SWG		River bank protection		PM, PR,CH	ML,HL	22
122	*Ixora malabarica* (Dennst.) Mabb.	Cherukuravu	VU	SWG				PR, BP	HL	22
123	*Memecylon deccanense* Clarke			SWG		River bank protection		BP	ML	22
124	*Memecylon randerianum* SM & MRAlmeida	Kashavu		SWG		River bank protection		PR	HL	22
125	*Strobilanthes ciliatus* Nees	Karimkurinji		SWG	YES			PM	HL	22
126	*Abelmoschus moschatus* Medik.	Kasthurivenda			YES			PM	ML	10
127	*Acanthus ilicifolius* L	Chulli			YES		YES (Man-grove)	CH	LL	20
128	*Ardisia elliptica* Thunb.					River bank protection	YES (Man-grove)	PM	HL	20
129	*Bambusa bambos* (L.) Voss	lli, Kaniyaram, Mula			YES	River Bank protection, RM for local livelihood		All	LL,ML,HL	20
130	*Capparis rheedei* DC.	Kakkamullu		WG	YES			CH	HL	20
131	*Melastoma malabathricum* L.	Athirani, Kadali, Kalampotta, Thodukkara			YES		YES	PM	ML	20
132	*Memecylon angustifolium* Wight	Aattukanala				River bank protection		PM	HL	10

133	*Memecylon umbellatum* Burm.f.	Anakombi, Kasavu,Kay-apoomaram, Anjanamaram			YES	River bank protection		PM, PR	ML,HL	20
CLIMBERS										
134	*Dioscorea wightii* Hook.f.			Kerala	YES			PR	HL	15
135	*Calamus travancoricus* Bedd. ex Becc.	Arichooral, Cheruchooral, Vallichooral		SWG		RM for Livelihood		PM	ML,HL	12
136	*Dioscorea kalkapershadii* Prain & Burkill			SWG	YES			PM	ML,HL	12
137	*Strychnos vanprukii* Craib	Mothirakanji-ram		SWG		River bank Protection		PM	HL	22
138	*Cayratia pedata* (Lam.) A. Juss. ex Gag-nep.	Corivalli	VU		YES			PR, BP	ML,HL	20
139	*Dalbergia volubilis* Roxb.	Valliyeetti, Mruithi			YES	River bank protection		PR	HL	20
140	*Derris trifoliata* Lour.	Poonjali, Ponnamvalli				River bank protection	YES	PM, PR,CH	LL,ML	20
141	*Hiptage benghalensis* (L.) Kurz	Njarambodal			YES	River bank Protection		PR,CH,BP	ML,HL	20
142	*Salacia fruticosa* Heyne ex Lawson	Korandi		WG		River bank protection		PM, PR	HL	20
143	*Salacia oblonga* Wall. ex Wight & Arn.	Ponkorandi				River bank Protection		PR	HL	10
HERBS										
144	*Eriocaulon periyarensis* Sunil & Naveen Kumar			Kerala			YES	PR	HL	25
145	*Fimbristylis narayanii* C.E.C. Fisch.			Kerala			YES	CH	HL	15
146	*Dalzellia gracilis* C.J. Mathew			SWG			YES	CH	HL	22
147	*Indotristicha ramosissima* (Wight) van Royen			SWG			YES	PR	ML	22
148	*Cryptocoryne spiralis* (Retz.) Fisch. ex Wydler					Water Purification	YES	PM, PR	LL,ML,HL	20
149	*Grangea maderaspatana* (L.) Poir.	Nelampala			YES		YES	PM, PR,BP	LL,ML	20
150	*Haplanthodes neilgherryensis* (Wight) Majumdar			WG	YES			CH	HL	20

151	*Heliotropium indicum* L.	Thelkkada, Napacha			YES		YES	PM, PR,BP	ML,HL	20
152	*Mollugo pentaphylla* L.	Parpadakapullu			YES		YES	All	ML,HL	20
153	*Persicaria barbata* (L.) H.Hara	Veluthamuthal-amoo kku			YES		YES	PM, PR, BP	LL,ML, HL	20
154	*Persicaria glabra* (Willd.) M.Gómez	Kozhivalan			YES		YES	PM, PR,BP	LL,HL	20
155	*Persicaria hydropiper* (L.) Spach.				YES		YES	PR	HL	20
156	*Portulaca oleracea* L.	Kozhuppa			YES		YES	PR, BP	HL,ML	20
157	*Saccharum arundinaceum* Retz.	Naimana			YES	River bank protection		All	LL,ML	20
158	*Wedelia chinensis* (Osbeck) Merr.	Manjakanjunni, Kadal-kayyonni			YES		YES	PM	ML	20
LOW PRIORITY SPECIES										
TREES										
1	*Baccaurea courtallensis* (Wight) Müll.Arg.	Mootikaya, Moottilazham, Mootilthoori		PI		River bank Protection, Fish Breeding		PM, PR,CH	HL	18
2	*Flacourtia montana* Graham	Lubikka		India		River bank Protection, Animal food		CH	HL	18
3	*Litsea coriacea* (Heyne ex Meisner) Hook. f.	Mulakunari, chevukodi		PI		River bank protection		PR,CH	HL	18
4	*Olea dioica* Roxb.	Edala, Vayila, Palarana		India	YES			All	ML,HL	18
5	*Terminalia paniculata* Roth	Maruthu, Pullamaruthu, Manjamaruthu		PI	YES			All	ML,HL	18
6	*Syzygium malabaricum* (Bedd.) Gamble	Kattuchamba		SWG				PR	HL	12
7	*Syzygium mundagam* (Bourd.) Chithra	Mundagam		SWG				CH	HL	12
SHRUBS										
8	*Alstonia venenata* R. Br.	Theeppala		PI	YES			PR	HL	18
9	*Memecylon molestum* (Clarke) Cogn.			PI		River bank protection		PR,CH	HL	18
10	*Mussaenda frondosa* L.	Parathole, Vellila, Vellilathaali		PI	YES			All	ML,HL	18

11	*Phyllanthus lawii* Graham ex Muell			India		River bank Protection Fish breeding		PR	HL	18
12	*Blepharistemma serratum* (Dennst.) Suresh	Nirkurunda		SWG				PM	ML,HL	12
13	*Grewia gamblei* Drumm. ex Dunn			SWG				PR	HL	12
14	*Hedyotis articularis* R. Br. ex Wight & Arn.			SWG				PR	ML,HL	12
15	*Ixora lanceolaria* Colebr.			SWG				PM	HL	12
16	*Nothopegia travancorica* Bedd. ex Hook.f.	Avukkarum		SWG	YES			PM	ML	12
17	*Osbeckia wynaadensis* Clarke	Vayanadan athirani		SWG				PR	HL	12
18	*Premna glaberrima* Wight.			SWG				PR	HL,ML	12
19	*Psychotria anamalayana* Bedd.			SWG				CH	HL	12
20	*Psychotria connata* Wall.	Kattukappi		SWG				PR	HL	12
21	*Psychotria flavida* Talbot			SWG				PM, PR	HL	12
CLIMBERS										
22	*Aganope thyrsiflora* (Benth.) Polhill var. eualata (Bedd.) Thoth. & Das	Kuriyal		SWG				PR	HL	12
23	*Connarus sclerocarpus* (Wight & Arn.)S chellenb.	Njaraneelakari-kam		SWG				PM	HL	12
24	*Dalbergia horrida* (Dennst.) Mabb.var. horrida; Ansari	Aanamullu Jadavalli		SWG				PR, BP	ML	12
25	*Desmos viridiflorus* (Bedd.) Safford			SWG				CH	HL	12
26	*Ficus laevis* Blume var. macrocarpa (Miq.) Corner	Peyatthi		SWG				PR	HL	12
27	*Millettia rubiginosa* Wight & Arn.	Kattadabu		SWG				PR	HL	12
28	*Quisqualis malabarica* Bedd.	Sandhyarani		SWG				PR	HL	12
29	*Smilax wightii* A. DC.	Karivilanthi, Chooramullu		SWG				BP	ML	12
30	*Strychnos lenticellata* Hill			SWG				PR	HL	12
	EN-Endangered; CR- Critically endangered; VU- Vulnerable; BP - Bharathapuzha; PI- Penisular India; WG-Western Gats; SWG- Southern Western Ghats; CH - Chalakudiyar LL- Lowland; ML- Midland; HL- Highland; PM – Pmampayar; PR - Periyar									

Table 23 River basin management plan						
Activity	**Sub Activity**	**Institutional Responsibility**	**Departmental Support**	**Technical Support**	**Duration**	**Remarks**
I. PLANNING PHASE : DEVELOPING SUB WATER SHED LEVEL MANAGEMENT PLAN (6 MONTHS)						
Formation of local body level Technical committee for planning and monitoring activities	GP President/Municipal Chairman or a person nominated by him/her from any of the standing committee presidents as Chairman and development standing committee president as vice Chairman and executive committee with all ward members, CDS chair person and 3-5 persons nominated from educational institution/Govt. department/ NGO in the local body	Local body more particularly the BMCs	LSG Dept. & Haritha Keralam Mission	KSBB, KSLUB Suchithwa Mission And other local R&D organizations	Within two weeks on initiation of the program	Data regarding the number of sub water sheds in the river basin, number of houses etc. has to be considered for forming neighbourhood groups .
Formation of neighbourhood groups for data collection and future monitoring	Sub watershed and local body based groups covering 25-30 houses depending upon the density of houses	-Do- (Ward member)	-Do-	-Do-	Within one month on initiation of the program	
Selection of local body ward level volunteer groups for data collection and supervision of activities	Two persons from each neighbourhood groups will be selected as volunteers	-Do- (Ward member)	-Do-	-Do-	-Do-	
Formation of local body ward level committee for monitoring activities	Ward member as convener and one member of the volunteer groups in the ward and a representative of an educational institution/Govt. department/ or NGO as Jt. Conveners and executive committee representing all educational institution/Govt. department/ CDS/ NGO in the ward	-Do- (Ward member)	-Do-	-Do-	-Do-	
Formation of Block level Technical committee for	Block Panchayat President or a person nominated by him/her from any of the standing committee presidents as Chairman and	Block Panchayat	-Do-	-Do-	-Do-	This committee can recommend activities to be
planning and monitoring activities	development standing committee president as vice Chairman and executive committee with all elected members, presidents of GPs, CDS chair person and 5-10 persons nominated from educational institution/Govt. department/ NGO in the block. The MLAs representing in the area may also be included in the committee as patrons					implemented through their working plan and also by the departments coming under them

Formation of District level Technical committee for planning and monitoring activities	District collector/District Panchayat president as Chairman and development standing committee president as vice Chairman and executive committee with all elected members coming under the VRB area, presidents of Block Panchayats and GPs, all departments and R&D institution heads and 5-10 persons nominated from reputed NGO in the block The MLAs representing in the area may also be included in the committee as patrons	District collector/District Panchayat	-Do-	-Do-	-Do-	This committee can coordinate overall activities and recommend projects from district Panchayat and various line departments
Compiling and coalition of various thematic maps and preparation of cadastral level GIS based mobile application for participatory data collection	District Collector/ District Panchayat through district level technical committee may identify suitable institution and allocate some funds under river management fund.. Environmental and socio economic data from each households and properties shall be collected. This include water availability, water use, issues related to streams, ponds rivers etc., sanitation facilities, waste management etc., heritage/Aesthetic sites, biodiversity etc. Detailed questionnaires shall be prepared for each category.	District administration	-Do-	KSREC, KSULB & CED	Within three months on initiation of the program	
Conducting two level training to the volunteers selected for participatory data collection	5-10 selected volunteers from each local body shall be given master training and they may train all the volunteers in each Panchayat	Designated agency by District administration	-Do-	KSREC, KSULB & CED	Within 45 days on initiation of the program	
Participatory data collection	Two volunteers taken each neighbourhood groups shall be combined at sub watershed level and they will be collecting the data using the mobile application.	-Do-	-Do-	-Do-	Within 3 months on initiation of the program	
Data analysis and developing project document with all data at Local Body ward level and draft activities for each sub watershed	The data will be analysed at the central level and management plan shall be prepared. Activities to be under taken step by step to be prepared. The soil erosion control activities shall be started first from the high elevation areas	-Do-	-Do-	-Do-	Within 4 months on initiation of the program	
Panchayat level plan discussion and finalization of year wise projects for implementation and funding sources	Meetings at different tiers, Grama Panchayat, Block Panchayat and District Panchayat. Step by step action plans to be finalised. The river bank protection activities in the steep areas shall be implemented after controlling all activities leading to that	-Do-	-Do-	-Do-	Within 6 months on initiation of the program	

II. IMPLEMENTATION PHASE: ACTIVITIES SUGGESTED BASED ON THE PRESENT STUDY (3 YEARS).						
Proper awareness creation among people and capacity building of all officials related implementation	Knowledge Centre for Environmental Planning (KCEP) with emphasis to river basin management. Onsite training to trainers and officials People participation in planning Pooling local HR and Expertise. Regular IEC activities	Local Body	KSBB LSG Dept., Haritha Keralam Mission,	KSREC, KSULB, CED	Within one year on initiation of Implementation Phase	
Increasing stream flow and ground water recharging	Planning in barren areas to check soil erosion and reducing velocity of runoff (locally available plants). Establishing rain water harvest pits and recharging domestic wells. Improved agricultural practices (Trenches coconut, plantain etc., Mulches and cover crops - All crops etc. Rejuvenation of degraded ponds and construction of new ponds Removal of blocks in the streams and ensuring free flow in the streams	Local Body	KSBB LSG Dept., Haritha Keralam Mission, Soil Conservation Dept., Social Forestry	KFRI CWRDM JNTBGRI, KSULB, CED	Within one year on initiation of Implementation Phase	
Controlling Soil and Water Pollution	Cleaning of streams and other Water bodies Providing proper sanitation facilities Solid Waste Management (Household waste as well as waste generated in public places Waste Water Management Waste water Treatment plants in markets Modern Abattoirs Organic farming practices	-Do-	-Do- Plus Agriculture Department	Suchithwa Mission, KRWSA, KSCADC, Agriculture Department	Within 2 years on initiation of the program	External funding shall be available from various agencies like NABARD (RIDF hemes)
Controlling Soil and Water Pollution	Cleaning of streams and other Water bodies Providing proper sanitation facilities Solid Waste Management (Household waste as well as waste generated in public places Waste Water Management Waste water Treatment plants in markets Modern Abattoirs Organic farming practices	-Do-	-Do- Plus Agriculture Department	Suchithwa Mission, KRWSA, KSCADC, Agriculture Department	Within 2 years on initiation of the program	External funding shall be available fro various agencies like NABARD (RIDF schemes)
Protecting rivebanks and conservation of riparian vegetation	Vegetative Protection using locally available plants based on its conservation value, location wise need/utility etc Inventory on the riparian flora and identification and prioritization of locally available/lost species in the area Gabion based engineering structures allowing natural vegetation	-Do-	-Do- Plus Minor& Major Irrigation Dept.	KFRI CWRDM JNTBGRI, KRWSA, CED	Within 3 years on initiation of the program	The prioritised list of plants for available in the four rivers is provided by the present study. More studies shall be initiated in other rivers also along with man

						agement action plan for each river.The RiverManagement Fund from Central Govt. available with district collector shall be utilised
Socio-economic Development through wise use of resources	Providing power supply in remote areas by establishing small dydel projects, Promoting other renewable energy sources like Solar,Wind etc.. Conservation of heritage and other suitable sites and developing Recreation/ Education/Tourism activities. Developing plans for wise use of riverine resources, value addition, responsible tourism etc. Plan for conservation of important species, its regeneration and wise use – Fishes, Medicinal Economically important plants	-Do-	LSG Dept., Haritha Keralam Mission	EMC Kerala ANERT Dept. Of Archaeology, JNTBGRI, Department, Agri. Dept., Medicinal Plant Board, KITTS etc	Within 3 years on initiation of the program – Shall be taken up Parallel KFRI Fisheries	
III. FOLLOW UP PHASE (CONTINUOS ACTIVITY)						
Ensuring completion of all activities envisaged	Discussing monitoring reports from the bottom (neighborhood group to District Technical Committee), finding out lags and action for completion	District Administration	KSBB LSG Dept., Haritha Keralam Mission	All agencies involved	Within 6 months after completion period	
Proper Documentation of all activities and Impact Assesment	Detailed project implementation report and impact assessment study	-Do-	-Do-	-Do-	Within 10 months after completion period	
Plan for continuous monitoring and permanent institutional set up	Policy decision making on continuing the monitoring activities based on the assessment and developing institutional set up	District Administration with Govt. support	-Do-	-Do-	Within one year after completion period	
ANERT: Agency for Nonconventional Energy and Rural Technologies CED: Centre for Environment and Development. CWRDM: Centre for Water Resources; Development and Management EMC: Energy Management Centre Kerala KRWSA: Kerala Rural Water Supply Agency. KSCADC: Kerala State Coastal Area; Development Corporation Limited. KSBB: Kerala State Biodiversity Board, KSEB: Kerala State Electricity Board KSLUB: Kerala State Land Use Board.; KSREC: Kerala State Remote Sensing and Environment Centre						

Impact of floods/ landslides on Biodiversity *Details of Project awarded to R&D Institutions and Universities*	
1	***Assessment of Impact of floods/landslides on Biodiversity with special emphasis on - Riparian vegetation - Pamba, Periyar, Chalakudy, Bharathapuzha.*** **Dr. BabuAmbat and Dr. Sabu T.,** Centre for Environment and Development, Thiruvananthapuram
2	***Riverine biodiversity monitoring with reference to Mangroves in comparison with preflood data.*** **Dr. Sarita G. Bhat and Dr. Sreekanth P.M.,** Department of Biotechnology Cochin University of Science and Technology, Kochi
3	***Impact of Floods / Landslides on Reverine Biodiversity - Chalakudy river basin.*** **Dr. P.O. Nameer,** Professor & Head (Wildlife) & The Dean of the Academy of Climate Change Education (ACCER), KAU, Thrissur.
4	***Impact of Kerala Floods / Landslides on single location endemic fish species.*** Dr. Rajeev Raghavan, Asst. Professor, Dept. of Fisheries Resource Management, Kerala University of Fisheries and Ocean Studies, Kochi.
5	***Assessment of Biodiversity Loss for Selected Faunal Groups.*** **Dr. Renjan Mathew**, State Director, WWF-India, Thiruvananthapuram,
6	***Post flood habitat modification and biodiversity loss in selected forest ranges in Palakkad District.*** **Dr. Maya C. Nair**, Assistant Professor, Post Graduate & Research Department of Botany, Govt. Victoria College, Palakkad.
7	***Assessment of Plant diversity including Aquatic flora Riparian vegetation etc in the flood / Landslides affected areas of Chaliyar, Korapuzha and Kuttiuyadi rivers.*** **Dr. N. S. Pradeep**, Senior Scientist, KSCSTE-Malabar Botanical Garden and Institute for Plant Sciences, Kozhikode.
8	***Impact of Landslides on the Forest Ecosystem in Wayanad district, Kerala with special reference to floristic wealth.*** **Dr. R. Prakash Kumar and Dr. Deepu Sivadas**, Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Thiruvananthapuram.
9	***Impact of Flood and Deluge on the Hydrobiology and Biodiversity endowments of Kuttanad Ecosystem, Kerala.*** **Dr. K.G. Padmakumar**, Director, International Research and Training centre for Below Sea level Farming (IRTCBSF), Alappuzha.
10	***Impact of the flood on soil biota in Pamba, Periyar, Bharathapuzha and Chalakkudy Rivers in Kerala.*** Dr. Sreekumar V.B., Kerala Forest Research Institute, Peechi, Thrissur.
11	***Assessment of Native And Exotic Ichthyodiversity Status Of River Bharathapuzha, Periyar And Pamba.*** **Dr. F.G. Benno Pereira**, Assistant Professor, Dept. of Zoology, University of Kerala, Kariavattom, Trivandrum.
12	***Survey and Inventory of Soil Microbial Biota in the Post Flood Scenario.*** **Dr. Shiburaj S**., Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Thiruvananthapuram,
13	***Inventory and evaluation of spread ecology of the reverine flora of Achankovilriverbasin, Kerala.*** **Dr. P.M. Radhamany**, Professor, Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram
14	***Impact of Flood on the Micro and Macro Floral Biodiversity of Pandalam & Chengannur with Special Reference to Pandanad: A Post and Pre-Flood Analysis, Kerala.*** **Dr. Jitesh Krishnan R,** Asst. Professor, Dept of Botany, NSS, College, Pandalam, Patahanamthitta.
15	***Biodiversity Assessment of Manimala River.*** **Dr. M. Rajendraprasad**, Scientist, Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Thiruvananthapuram,
16	***Studies on Invasive Alien Plant Species in the flood affected areas of KarthikapallyTaluk, Alappuzha District.*** **Dr. Suhara Beevy S.**, Associate Professor & Head, Department of Botany, University of Kerala, Kariavattom, Thiruvananthapuram

17	***Estimation of Population density and diversity of major soil animal groups in relation to recent flood affected areas near Pampa River.*** **Dr. M.G. Sanal Kumar,** Asst. Professor and Research Department of Zoology, NSS College, Pandalam, Patahanamthitta.
18	***Riverine Biodiversity Monitoring - Impact of Floods/Landslides on Biodiversity.*** ***Dr. N. Shibin Mohanan,*** Asst. Professor and FLAIR - Kerala Faculty Nirmala College, Department of Botany, Muvattupuzha
19	***Inventory and evaluation of spread ecology of the Mangrove flora in the islands of Alappuzha District***. **Dr. Jose Mathew**, Asst. Professor, Department of Botany, Sanatana Dharma College, Alappuzha.
20	***Metagenomic analysis of soil microbia; diversity in post flood mangroves.*** **Dr. Sarita G. Bhat and *Dr. Bindiya B.S.***, Department of Biotechnology, Cochin University of Science and Technology, Kochi.
21	***Impact of Floods/landslide on Biodiversity and Evaluating the Change in the Ecosystem/ Biodiversity of the State. Dr. G. Suresh and Dr. A Satheesan***, Principal Coordinator Centre for Management Development, , Thiruvananthapuram
22	***Assessment of agrobiodiversity loss due to flood in Wayanad and Developing Conservation Strategies.*** **T. R. Suma**, Scientist, Community Agro-biodiversity Centre, M S Swaminathan Research Foundation, Wayanad.
23	***Assessing Impact of Floods/ Landslides on Biodiversity, Bioresources, and Tribal Livelihood in Attappady.*** **Dr. S. Sreekumar and Dr. K.K. Seethalekshmi,** IRTC, Integrated Rural Technology Centre (IRTC), Mundur, Palakkad
24	***Assessment of Impact of flood/landslide on Biodiversity and developing methodology for long-term monitoring and evaluation of changes in the ecosystem and biodiversity : A case study in the AthirapillyPanchayath.*** **Dr. Amitha Bachan K.H**., Assistant Professor & Research Guide, Department of Botany, MES Asmabi College, Thrissur.
25	***Assessment of Plant diversity loss along the flood and landslides hit areas of Nelliyampathi Forest Range, Palakkad.*** **Dr. Suresh V**. Assistant Professor, Department of Botany, Govt. Victoria College, Palakkad
26	***Assessment of Biodiversity loss along the flood and landslide hit areas of Attappady region, Palakkad district Using Geoinformatics.*** **Dr. Richard Scaria**, Assistant Professor, Department of Geography, Govt. College Chittur, Palakkad
27	**Impact of floods/landslides on Biodiversity in Pathanamthitta and tribal Livelihood in Idukki and Pathanamthitta.** ***Dr. G. Suresh***, Project Director, Centre for management Development, Thiruvananthapuram
28	***Survey and analysis on Ethnobotanical resources present status and livelihood of tribal communities in flood affected areas of Vazhachal, Thrissur Dist.*** **Dr. E.A. Siril.** Associate Professor, Dept. of Botany, University of Kerala, Kariavattom Campus

KERALA STATE BIODIVERSITY BOARD

KERALA STATE BIODIVERSITY BOARD

9 788193 423134