Volume I

FINAL REPORT

ASSESSMENT OF IMPACT OF FLOOD/ LANDSLIDE ON BIODIVERSITY WITH SPECIAL EMPHASIS ON RIPARIAN VEGETATION IN PAMBAYAR, PERIYAR, CHALAKUDYAR AND BHARATHAPUZHA

Submitted to

KERALA STATE BIODIVERSITY BOARD

By

CED

CENTRE FOR ENVIRONMENT AND DEVELOPMENT

THIRUVANANTHAPURAM

JUNE 2019

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Worldwide, in recent years humans have suffered increasing numbers of natural disasters which resulted in the death of millions people, and also adversely affecting more than 100 times of people who died during the event. India is also not an exception for the world scenario with regard to the natural disasters. Kerala, a relatively small State comprising an area of 38863 Km^2 is drained by 44 rivers. The width of the State varies from 15 to 120 km. With the two rainfall pattern .i.e., south west monsoon and north east monsoon, undulating topography arising from geological formations, results in a near water logged conditions in almost 20% of the total geographic area of the State. Physiographically, the State comprises of three zones: the lowland (< 8 m from MSL), midland (8 to 75 m) and highland (> 75 m). The highland may be further subdivide into low highland (75 to 700m) and high highland/harangues (>700m). The three physiographical zones form roughly parallel belts running along the length of the State. The highland is situated in the eastern boundary comprising of high ranges of the Western Ghats; the lowland is a narrow strip along the coast; and the midland lies between the highland and lowland. The lowland is characterised by numerous lagoons and backwaters such as Vembanad, Ashtamudi, etc., which receive drainage from the rivers. A few kilometres from the sea to the east, the topography changes to cluster of lateritic hills with numerous valleys in between called *elas*. The low lateritic hills in this region are interspersed with paddy fields, coconut and arecanut groves.

The changing climatic dynamics and peculiar physiographic condition of the State amplifying with the climate change impacts, especially the extreme weather conditions predicted by various studies make the State as one of the most vulnerable States in India with respect to the natural disasters. Flooding and landslide/landslips are the two most severe natural disasters we are expecting in the near future.

During the months from June to August 2018, Kerala experienced many small and large flood and landslide events and the worst flood event ever since 1924 was occurred from 15th to 18th August 2018. Together with the flood there were many events of landslides in the hilly tracts (highlands) of the State. Nearly 350 landslides were reported in the State during this period. As per the Government records, 5.4 million people were affected and 1.4 million displaced by the destructive flood and landslides and 1,259 out of the 1,664 for villages in 14 districts of

the State were affected. Severe events were noticed mainly 10 districts. The disaster took 433 lives from the State.

The main reason attributed to the unprecedented flood and landslide is the high intensity rainfall received in the State for about two and half months (June to August 2018). The State received 42% more rains than usual since the onset of the Monsoon in June. By mid of August, there had been 2346.3 mm of rainfall instead of an average of 1649.55 mm. In the last three weeks of these months i.e., between 1st August and 19th the State received 758.6 mm rainfall, 164% more than the average of 287.6 mm which expected during this period. The cumulative rainfall received in India during 10th to 16th August 2018 published by India Meteorological Department (IMD) is given in Fig. 1.1.

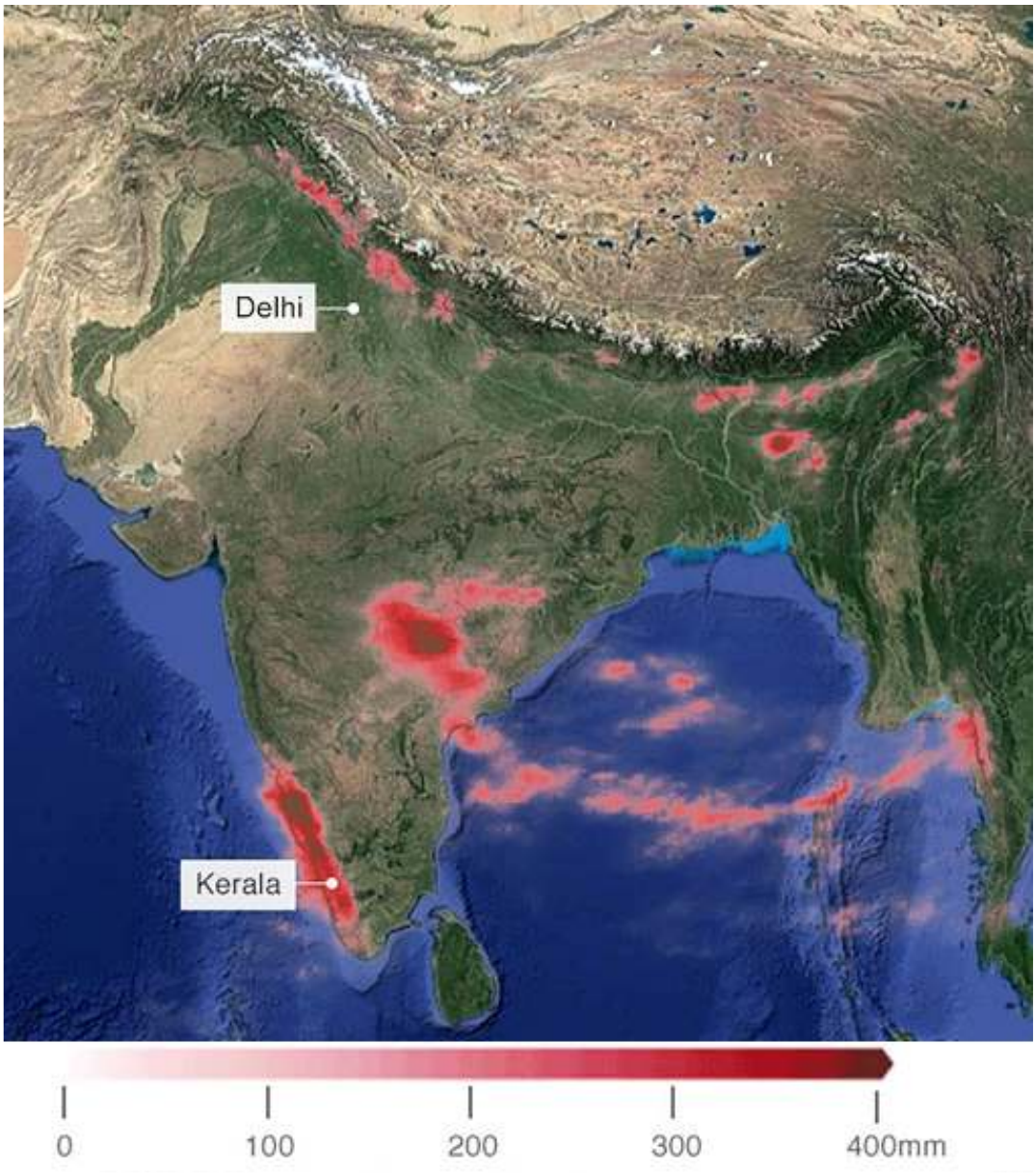

Fig. 1.1
Cumulative Rainfall received in India during 10th to 16th August 2018 (Source IMD)

A detailed analysis of the climatic and other conditions lead to the flood and landslide was done by the Central Water Commission (CWC, 2018) immediately after the flood and their report is available online at http://cwc.gov.in/main/downloads/KeralaFloodReport/Rev-0.pdf.

After the event there were many studies conducted by the State/Central Government departments/agencies and some non government agencies to assess the impact of the flood and landslides. However, most of them are concentrated on the physical and social impacts and none of the properly addressed the environmental impacts of the flood and landslide.

The post disaster needs assessment carried out by United Nations Development Program (UNDP, 2018) with help of Kerala Ministry for Revenue and Housing and the Kerala State Disaster Management Authority also has not gravely attempted this. However, they have suggested that the magnitude of the floods and landslides has underscored the need for research and knowledge generation activities. They have mentioned that *while downstream conditions hampered discharge of water, flooding was also a result of inappropriate human interventions in the middle and upper parts of river basins. There is a need therefore, for research on the role of deforestation, quarrying, unscientific road construction, slope modification, sand mining from river beds, construction on stream channels, narrowing and blocking of drainage channels and so on, in aggravating landslides and flooding. Such research outcomes can inform land-use maps for recovery and reconstruction projects, in particular road construction, location of hospitals and schools, and also for regular development planning.*

The one and only study hitherto attempted on the environmental impact of the flood and landslide was by the Kerala State Biodiversity Board (KSBB) in collaboration with the Biodiversity Management Committee (BMC) and the technical inputs from an array of research institutes and other experts in this field. This remarkable attempt has undertaken a Participatory Rapid Assessment on the Impact of flood and landslide to the biodiversity and other related aspects and was done by consulting all stakeholders in the State. In addition to various recommendations provided by the study for reconstruction based on ecological principles, it also recommended in depth studies on various impacts to provide inputs for an ecosystem based reconstruction at local level.

The present study is an attempt towards a rapid scientific assessment of the impact and is expected to analyze the impact of flood and landslide to the riparian flora in selected area of the state in order to provide some general recommendations for restoration and follow up activities and is funded by KSBB.

1.2 IMPORTANCE OF PRESENT STUDY

1.2.1 Riparian Vegetation

Safeguarding biodiversity has become a key societal concern in the light of global environmental change, particularly because biodiversity plays an important role in the provisioning of ecosystem services (Butchart, et al, 2010; Griggs. et al. 2013; Isbell et al. 2017).

River has become the focus of development as a major source of fresh water. It is the locus of life and the cradle of human civilization. River health is the material basis and assurance of human survival and economic development. Human development needs a healthy river system. Rivers possess a delicate ecology that depends on a regular cycle of disturbance within certain tolerances.

The issues related to river management are diverse in nature ranging from water quality in physical, chemical and biological terms, drainage of treatable waste, erosion of catchment, riverbank erosion, and accessibility to communities for use, overuse and impact on the river bed and conservation of biodiversity. The concept of river health originates from river ecosystem health, however, it is not confined to river ecosystem health as the river has both, natural and social attributes. Ecosystem health is important component of river health because it is formed by the interaction between river biota and their hydro-geochemical environment. Generally, a healthy river is river that can satisfy the sustaining need of human and maintaining health of river ecological environment.

Understanding the vegetation of an ecosystem or landscape unit is an important step in understanding the overall dynamics and functions of an ecosystem. Vegetation of an area is chiefly determined with latitude and longitude (geographical) position, climate, water availability or precipitation and also the physiographic and biotic features. The availability of water is an important factor determining vegetation of an area especially within a tropical condition, where availability of energy is abundant.

One of the major components of the river ecosystem health is the riparian vegetation. Plants seen along the river margins are generally referred as the riparian vegetation. The riparian areas are among the biospheres most complex ecological systems and also among the most important for maintaining the vitality of the landscape and its rivers (Naiman & Decamps 1997). The interface of land and water is the most productive systems of a landscape. 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 (Cummins 1974). Under normal circumstances riparian ecosystems support a prevalence of vegetation typically adapted for life in saturated soil conditions (Gosselink *et al.*, 1981).It is also known as gallery forests and streamside forests (Brinson, 1990). These can create a mosaic of microhabitats with the coexistence of numerous plant species (Swanson *et al.*, 1982; Gregory *et al.*, 1991).

Riparian landscapes are highly threatened ecosystems as they are inherently rare habitats, occupying a mere one-thousandth of the earth's surface (Hynes, 1970). The riparian ecosystems can be delineated from the surrounding landscapes by the demarcating the area of stream / river channel during flooding or augmentation of water bodies and water holding capacity of soils (Naiman *et al*., 1993). Geomorphic structures and distribution of plants that are tolerant to either flooding or drought are also helpful in delimiting riparian ecosystems (Nilsson, 1983).

Riparian vegetation is extremely important because of the many functions it serves. The very structure of the riparian vegetation of an area will be in accordance with the available climax vegetation, aquatic flora and geomorphic process in the natural environment. These also include various land use practices and other anthropogenic activities. The riparian plant communities are also influenced by the upstream and downstream (longitudinal) and transverse linkages of species recruitment and diversity (Vannote *et al.* 1980, Noss 1983, Newbold *et al.* 1981). *A* good number of studies are available from the temperate regions, but a few from the tropics on the significance of riparian vegetation. However, little is known about spatial patterns in the diversity of plant communities along riparian environment. (Decamps & Tabacchi 1993, Tabacchi *et al.* 1996).

Riparian ecosystems are located next to streams, rivers, lakes, wetlands and have direct influence on aquatic and wildlife habitat. Virtually all rainwater runoff must pass through the zone before moving into adjacent aquatic ecosystems. Further, the zone can be seen as an interface between terrestrial and aquatic systems and is described as a series of ecotones between these systems. The vegetation in this area ranges from emergent aquatic and semi-aquatic plants through to terrestrial understory and canopy species. The riparian vegetation plays a critical role in providing for a healthy stream system. The riparian, or streamside, plant community maintains the riverine landscape and moderates conditions within the aquatic ecosystem. As rainfall runs off the landscape, riparian vegetation help to: i) slows the rate of runoff, ii) captures excess nutrients carried from the land, iii) protects stream banks and floodplains from the erosive force of water, iv) regulates water temperature changes, v)

provides nesting/breeding grounds, food and cover to terrestrial and aquatic fauna and vi) conserves soil moisture, ground water and atmospheric humidity.

Like other vegetation types the riparian vegetation also influence or modify its surroundings. It becomes more significant influencing the riverine as well as the terrestrial environment. The function of the riparian vegetation in stream base stabilization (Beeson & Doyle 1995), water quality improvement (Tremolierers *et al.* 1997), controlling the future stream flow (Auble *et al.* 1994), role in shaping stream channels and biotic communities in a natural landscape are major areas of interest in the modern context of riparian and watershed based development and management.

When we consider the ecological impact of the flood, preliminary observations have shown that the riparian regions of the major rivers in Kerala are one of the areas which is highly affected by the August 2018 flood and landslide The high intensity flow of water through the rivers along with river bank slumping and continuous water inundation caused major changes to the riparian flora. In many places the entire vegetation is lost either due to bank slumping or due to inundation. Considering the importance of the area there is a need to conduct a detailed analysis on the impact of current rain ravage on the riparian flora of the rivers which has affected most severely and areas where we have some background data on the riparian vegetation is attempted here as experimental cases for a critical assessment .

CHAPTER 2

OBJECTIVES

Considering the importance of the riparian vegetation along the rivers in Kerala, the present study is aimed at assessing the impact of the recent floods/landslides on riparian vegetation in the three most severely affected major Rivers of Kerala viz. Pampa, Periyar and Chalakudy and the less affected major tributaries of Bharathappuzha.

The specific objectives are:

1. To identify and map the vegetation loss in the Pampa river, Periyar, Chalakudy river and some major tributaries of Bharathappuzha (Thoothappuzha, Kalpathippuzha and Gayathrippuzha) after flood.
2. To survey the current floristic diversity of the riparian regions of the above rivers and identify species lost due to flood and the extent of loss in comparison with pre-flood scenario. .
3. To analyze the impact of species loss with respect to its conservation importance like IUCN threatened status, endemism, breeding and nesting areas of animals, river bank protection etc.
4. To identify the species which has survived and the potential of using these species for future afforestation programs in the river banks in Kerala
5. To identify and prioritize areas for intervention and monitoring - based on the impact of the flood/landslide as well as the current distribution of species with conservation importance (Additional objective added on analysing the results)

CHAPTER 3
MATERIALS AND METHODS

3.1 DESCRIPTION OF THE RIVERS UNDER STUDY

Four major Rivers of the State, Pampayar, Periyar, Chalakudyar and Bharathappuzha, which were affected badly during the 2018 August flood/landslide were selected for the study. Among this the main river stretches were studied for the Pampayar, Periyar and Chalakudyar and for Bharathappuzha three major tributaries, Thoothappuzha (including part of Kunthippuzha), Kalpathippuzha and Gayathrippuzha alone were .studied.

3.1.1 Pampayar

Location and Geomorphology

The main Pampa River with a length of 176 km is the third longest river of Kerala. The entire catchment area lies in the State of Kerala, between 9^0 9.90' to 9^0 36.38 N latitude and 76^0 18.30' – 77^0 17.42' E longitude, entirely in the Kerala state (Idukki, Kottayam, Pathanamthitta and Alappuzha districts – (Plate 1).

The neighbouring basins are: Periyar (North-East), Manimala (North) and Achankovil (South). As per earlier reports (CWRDM, 1995) the catchment area of Pampa is 2235 sq km and is the fourth largest river basin of Kerala. However, as per the water shed map prepared by Kerala State Land Use Board (KSLUB) the Pampa basin has an area of 2089 sq km and considered as fourth largest basin next to Muvattupuzha (2675 sq km). The river Pampa takes its origin from the ridge formed by Chinnamel Malai, Poochi Malai, Nangamalai and Sundara Malai in the Western Ghats at an altitude of around 1676 m and flows in South-west and North-west direction with a number of falls. The upper reaches of the river is upper reaches was charged by 288 rivulets and streams. The major tributaries of the river are Azhutha Ar, Kochu Pampa Ar, Kakki Ar, Kakkad Ar, and Kal Ar (Plate 1).

The southern tributary of the main Pampa River is Kakki Ar. The Kakki Ar drains a wide stretch of the western slope of the Western Ghats, receives Chinnakakki Ar and Anathodu, and after a long meandering course through a rolling higher Gudarakal Plateau comes out of the hats through a narrow deep gorge running north - north-west parallel to and to the south-east of the Pampa gorge. It then flows north and joins the Pampa Ar at Triveni near Chalakkayam, located immediately to the south of Sabarimala Temple. The Kakki reservoir is in this sub-basin. The Kakkad Ar is formed by Moozhiyar and Manian Ar which their origin from the ridge formed by Valanjakadu Malai on the South Kakkiyar Malai and Palampara

Medu on the East and Puda Malai, Valia medu and Kollakunnu on the North; flows more or less in a westerly direction as far as Angamoozhi, thence southwards to Seethathodu and thence again westwards, it joins the Pampa Ar at Perinad. Pampa River from Perinad downwards is navigable.

The annual discharge of the river in the Midland (Malakara, Kurudamannil) is 3868 Mm^3 and lowland (Erapuzha) is 4056 Mm^3 (NEERI, 2003). About 90% this is during the monsoon. With its very significant annual discharge volume Pampa had a major role in the complex hydrological processes taking place in the Vembanad and Kuttanad tract. The basin experiences good rainfall, moderate temperature and humid atmosphere. The complexity of the terrain with many west opening valleys and hill slopes exposed to different directions occurring in this particular part of the Southern Western Ghats, extensive forest cover and range of elevations indicate considerable variation in weather and climate within the study area. The SW and NE monsoon have great influence over the climatic conditions. The annual rain fall varies from about 2700 mm. in the plains to about 4200 mm in the high lands. Average annual rainfall amount for different physiographic zones within the study area are given in Table 3.1. Most of the rainfall is brought by the South-west monsoon which often create torrential downpour causing heavy floods in the low lying areas. Due to the undulating nature of terrain the accumulated water are drained off quickly. The details of climatologically/rainfall data of the basin from 1978 is available from Angamoozhi, Perumthenaruvi, Maniyar, Pampa, Alappuzha, Anathode, Pullad State Seed Farm, Triveni, Vallathumuzhi and Chittar.

Table 3.1
Annual Average Rainfall of Pampa River Basin (NEERI, 2003)

Physiographic zone	Total Rainfall (mm)	No. of Rainy days	% of Rainfall Density		
			SW-M	NE-M	Others
Highland	3762	164	53	29	18
Midland	3225	114	45	31	24
Lowland	3298	131	50	30	20

The temperature varies between 19^{o}C and 36^{o}C and the seasonal variations are not very wide. At higher altitudes the temperature is considerably less during the winter months and frost occur during this period. The humidity at the foot hills varies from 70 to saturation, whereas at higher attitudes it is slightly less.

Like all the river basins in Kerala, the Pampa and the Achankovil basins also can be divided into three natural zones based on elevation, consisting of low land (< 7.5 m), midland (7.5-75 m) and high land (>75 m). The highland area occupies 74% of the total basin area (1543 sq km), midland 7% (145 sq km) and lowland 19% (401 sq km). The land use pattern of this river basin is unique and diverse. A major portion of the basin, approximately 1200 sq.km. is forestland. Only Chalakudy River in Kerala has such a high proportion of the basin under forest cover. Hence potentially Pampa could be a very healthy river without any drastic reduction in the lean season flow.

Land use and Biodiversity

A broad classification of the land use types in Pampa river basin as per the study by CED (1997) is given table 3.2.

Table 3.2
Land use/Land cover

Land use/Land cover	Area	% of area
Agriculture- Paddy	142	6.8
Agriculture- Mixed crops	426	20.4
Agriculture – Large scale Plantation	213	10.2
Forest excluding grassland	1130	54.1
Grass land	52	2.5
Forest plantation	20	1.0
Built-up area	25	1.2
Reservoir area	40	1.9
River and other water body	41	2.0
Total	**2089**	**100**

About 58% of area under forest (including grass lands and forest plantations. The second largest land use class mixed crops which are mostly concentrated in the midland and low land regions. Large scale agricultural plantations (mostly rubber) are concentrated in highland area. Most of the earlier Cardamom plantation areas are now in an abandoned stage.

Various studies have shown that large scale land use changes have occurred in the basin area during the last few decades. One of the major studies conducted recently on the land use changes in the Pampa river basin is by Mayaja and Sreenivasa (2017). They analysed the changes for the years 1985, 1995, 2005 and 2012 and mapped it using GIS and remote sensing tools. The land use map pertaining to the years 1985 and 2012 corresponding to each category according to the study is provided in Fig. 3.1.

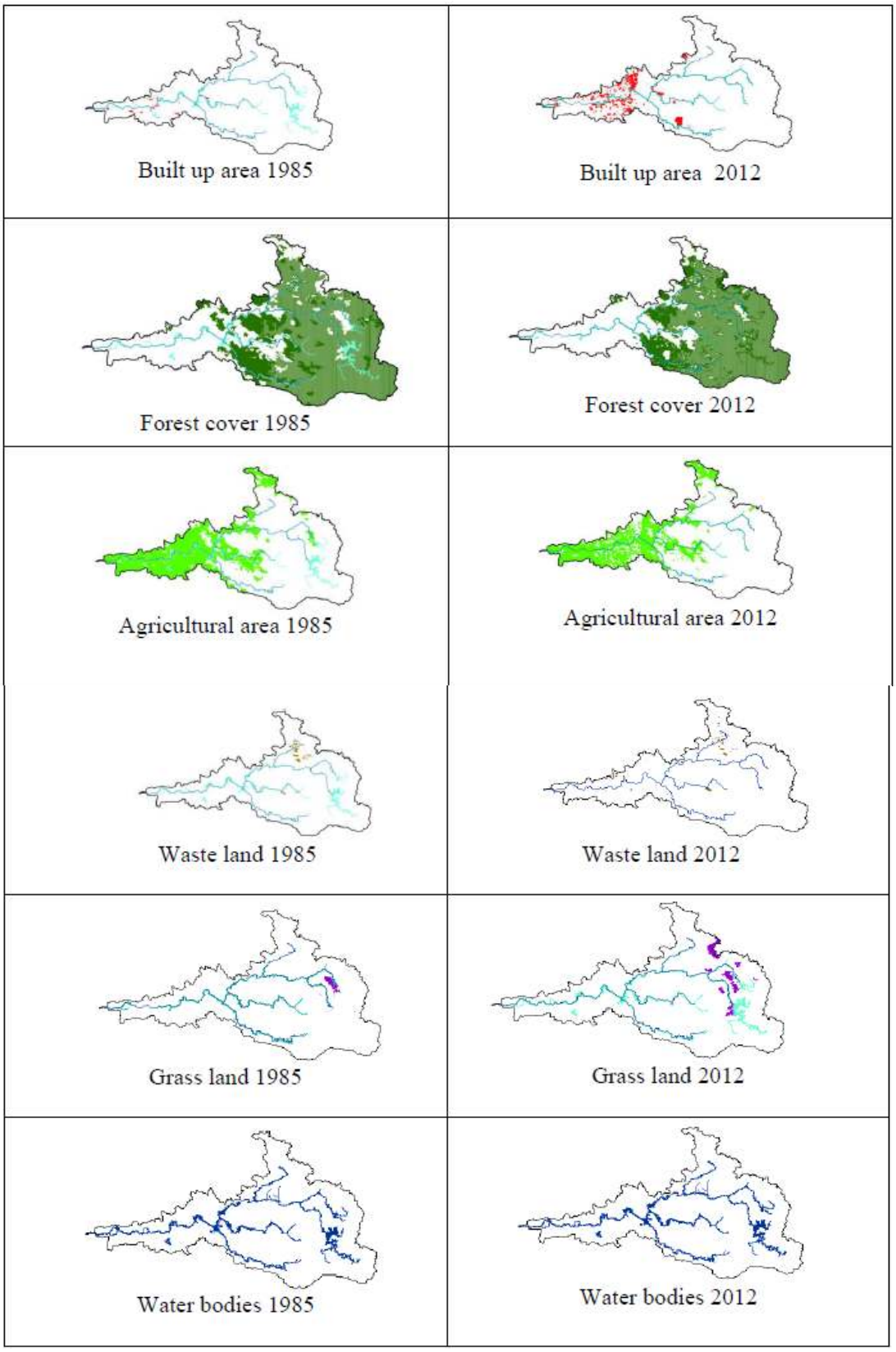

Fig. 3.1
Land use changes in Pampa Basin (Mayaja and Sreenivasa, 2017)

The most significant observations in this study are the 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%).

The very unique land use pattern, undulating topography, vibrant climate and vivacious hydrology of this river basin provide multitudes of lively micro ecosystems. The high land consists of high altitude areas of thick forests whereas midland consists of region of cash crops like rubber and tea. The low land is basically providing agrarian crops like paddy, vegetable and coconut. The kole lands in the lowland areas are considered as a very unique wetland ecosystem.

With a predominance of forest landscape, the river basin area has very biodiversity with respect flora and fauna. A rapid assessment of Biodiversity of the Gudarakal Range, Ranni Forest Division coming under Pampa basin was conducted by Periyar Foundation and Kerala Forest Department (Periyar Foundation, 2006). The taxonomic cataloguing appended with the study lists more than 1250 species of flowering plants, 150 species of birds apart from a number of representatives of the other faunal groups. Most of the floristic data available on Pampa basin is on the upper catchment area. The tropical Evergreen Forests are characterized by numerous epiphytic species especially aroids, ferns, mosses and orchids.

Majority of the area coming under highland and part of midland basins of Pampa is covered in the flora of Pathanamthitta district by Anilkumar et. al (2005). The flora presents a systematic account of a total of 1249 species belonging to 658 general of 148 families of seed plants. The species index is registered as 460/1000 sq km which is comparatively very high and indicates the richness of the floristic diversity of the district. Seven new species and two new varieties have been discovered from the district. An analysis of the flora showed that 260 species are endemic which formed 22% of the total species. About 200 species are rare and 175 are severely threatened; most of which are local endemics. A total of 90 wild relatives of cultivated crop plants have been collected.

The flora of Alappuzha district prepared by Sunil and Sivadasan (2010) consist of description plants of entire lowland area and part of the midland of Pampa basin.

A detailed study on the riparian vegetation of Pampa basin was attempted by Joby Paul (2012). The study identified 545 angiosperms belongs to 119 families, 3 gymnosperms belongs to 3 families and 31 pteridophytes in 16 families.The 6 most dominant families area; Rubiaceae (37 spp), Fabaceae (36 spp), Poaceae (35), Euphorbiaceae (19 spp), Commelinaceae (18 spp) and Cyperaceae (18 spp), It includes a new distributional record of *Hanguana malayana* (Jack) Merr. in the geographical limits of India and rediscovery of *Diospyros sulcata* Bourd. after 102 years of the type collection. 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. The analysis of the floristic elements shows that 20.55% species of the Pampa river basin are native (119 species) and among them 114 are endemic to various geographical boundaries of India. The species endemic to Western Ghats (57 species) and the Southern Western Ghats (36 species) share the major percentage of endemism in the Pampa river basin. Among the endemics, 32 are red listed plants, including 19 RET species distributed in the isolated riparian forest pockets with small population so that the threatened ecosystem status of Malanson (1993) is corroborated.

The forests of the Pampa basin, adjacent to Periyar Wild Life Sanctuary are rich in wild life. As these forests are not easily accessible and are far away from habitation, wild life to a certain extent find a free and peaceful life in this forest. There is frequent seasonal migration of animals in large herds from the sanctuary to these areas and vice versa. The vegetation present in these reserves along with the perennial water holes and marshes create an ideal environment for the dwelling of wild animals in this region. We can see the wild animals moving around the vicinity of the Sabarimala Sannidhanam and Pampa Ganapathy temple during off seasons. The overall findings of the Periyar foundation study (2006), is that Gudarakal Range has a very rich mammalian fauna in particular with a large population of elephants. The area also has more than one Nilgiri Tahr population. Evidences indicate a very healthy population of all the other wild ungulates typical of the Western Ghats forests. The primate population is also recorded to be very healthy and includes lion tailed macaques. The Periyar Tiger Reserve and the adjacent Gudarakal Range combined would potentially have numerically the largest assemblage of the wild mammals of the Western Ghats. About 150 bird species were recorded by a five-day field survey by Periyar Foundation (2006) in the Gudarakal Range alone. The Periyar Tiger Reserve adjacent to Gudarakal Range is reported to have more than 270 bird species (Robertson & Jackson, 1992). The short survey by Periyar Foundation (2006) has recorded the presence of 7 out of the 16 species of birds endemic to the Western Ghats. Direct observations during the survey indicated a good population of the Great Hornbill and hence in any conservation measure to protect this typical endangered rainforest bird, Gudarakal forest should have a pre-eminent position. The varied ecosystems found in the upper catchment would be harbouring a rich reptilian fauna including snakes, tortoises, monitor lizard and other species of lizards, skinks and geckos. During the biodiversity survey only a few species of snakes and the monitor lizard were recorded.

Studies have so far recorded 60 fish species from the Pampa basin so far even though many areas within the basin remain to be explored. Out of the 60 species so far recorded from the Pampa basin 16 are endemic to the Western Ghats and 8 are endemic to the Kerala part of the

Western Ghats. This is an exceptionally high degree of endemism for a small basin covering just over 2200sq km. area. One of the sixty species so far collected from Pampa i.e. *Puntius ophicephalus* has so far been collected only from Pampa and Periyar rivers. Menon (1999) has included it in the endangered category. Some introduced species have also become established in this basin. Three such species have been recorded so far and one of them was collected from the uppermost reaches of the Pampa tributary. Radhakrishnan and. Kurup (2010) has studied Ichthyodiversity of Periyar Tiger Reserve which included a small part of Pampa basin (three locations: Pampa, Azhutha and Pachakanam). Out of the 54 species recorded 39 are found in the Pampa region of which 24 are found only in this area. This includes 4 endangered species (*Puntius denisonii, Garra surendranathanii, Batasio travancoria and Glyptothorax annandalei*) and 7 out of the 9 vulnerable species recorded from the whole area. The fishes of the Perumthenaruvi region of the Pampa River were studied by Thomas John (2004).

The vast majority of fauna fall within the invertebrate groups. The tropical rainforest harbour an exceptional wealth of insect fauna. The freshwater bodies and the rivers which abound in the Gudarakal Range would have a rich assemblage of aquatic invertebrate fauna. But there is no concentrated effort to study the invertebrates in this area. The butterfly fauna alone was partially studied. A detailed study of the aquatic invertebrate fauna particularly the dragonflies will be very valuable because of the potential list of species occurring in the area. Because of the wide range of major taxonomic groups within invertebrates, each requiring specialist taxonomists, no attempt was made to collect them or identify them. This is a long-term work but should be started as early as possible because invertebrate fauna, particularly insects, play a very crucial role in the rainforest dynamics.

Socioeconomic Profile

There are 74 local bodies (72 Panchayats and 2 Municipalities) associated with the river basin fully or partially (Table 3.3). Of these 24 are entirely in the highland (of these part of 6 GPs are in the High high land area) , 4 in highland and midland, 14 entirely in midland, 4 in midland and lowland and the balance 30 are entirely in the lowland. The main river or major tributaries (Azhutha Ar, Kochu Pampa Ar, Kakki Ar, Kakkad Ar, and Kal Ar) of the river is flowing through 48 Local bodies (46 Panchayats and 2 Municipalities). Major towns (urbanised areas) associated with the basin include Alappuzha, Ambalappuzha, Karuvatta, Harippad Chambakulam, Thakazhi, Edathwa, Niranam, Mannar, Chakkulathkavu,

Chengannur, Aranmula, Ayiroor, Kozhencheri, Cherukolpuzha, Naranganam, Uthimoodu, Kumbalampoika, Vadaserikkara, Chittar, Seethathode etc.

Table 3.3
Local Bodies in Pampa River Basin

Sl. No.	Local Body Name (Panchayat/Municipality)	Sl. No.	Local Body Name (Panchayat/Municipality)	Sl. No.	Local Body Name (Panchayat/Municipality)
IDUKKI DIST					
1	Kokkayar (HHL/HL)	3	Peerumedu (HHL/HL)*	5	Peruvanthanam (HHL/HL)*
2	Elappara (HHL/HL)	4	Vandiperiyar (HHL)	6	Kumily (HHL/HL)*
KOTTAYAM DIST					
7	Mundakkayam (HL)	8	Erumeli **(HL)***		
PATHANAMTHITTA DIST					
9	Seethathode(HL)*	21	Thannithode(HL)	33	Thottapuzhassery (ML)*
10	Chittar(HL)*	22	Konni(HL)	34	Ezhumattoor(ML)
11	Vechuchira(HL)*	23	Malayalappuzha(HL)	35	Puramattom(ML)
12	Naranammoozhi(HL)*	24	Mylappra(HL)	36	Koipram(ML)*
13	Ranni-Perunnadu(HL)*	25	Naranganam(HL/ML)	37	Iraviperoor (ML)
14	Vadaserikkara(HL)*	26	Elanthoor(HL/ML)	38	Kuttoor (ML)
15	Ranni-Pazhavangadi(HL)*	27	Chenneerkkara(HL)	39	Aranmula (ML/LL)*
16	Ranni-Angadi(HL)*	28	Omalloor(HL)	40	Kadapra (LL)*
17	Ranni(HL)*	29	Cherukole (H/MLL)*	41	Niranam(LL)*
18	Kottanadu(HL)	30	Ayiroor (HL/ML)*	42	Mezhuveli (LL)
19	Kottangal(HL)	31	Kozhencherry (ML)*		
20	Aruvappulam(HL)	32	Mallappuzhassery*		
ALAPPUZHA DISTRICT					
43	Chengannur MPTY (ML/LL)*	54	Ramankary(LL)*	65	Karuvatta(LL)*
44	Mulakkuzha (ML/LL)	55	Thalavadi(LL)*	66	Purakkadu(LL)*
45	Ala (LL)	56	Edathwa(LL)*	67	Ambalapuzha South(LL)*
46	Cheriyanadu (LL)	57	Champakulam(LL)*	68	Ambalapuzha North(LL)*
47	Puliyoor (LL)	58	Nedumudi(LL)*	69	Punnapra South(LL)*
48	Pandanadu (LL)*	59	Thakazhi(LL)*	70	Punnapra North(LL)*
49	Thiruvanvandoor (LL)*	60	Kainakary(LL)*	71	Alappuzha Municipality(LL)*
50	Bhudhanoor (LL)	61	Veeyapuram(LL)*	72	Aryadu (LL)*
51	Mannar (LL)*	62	Harippad(LL)	73	Mararikulam South(LL)
52	Chennithala-Thripperunth (LL)	63	Kumarapuram(LL)	74	Mannanchery(LL)
53	Muttar (LL)	64	Cheruthana (LL)*		

**Main river passing LBs HHL – High Highland HL-Highland, ML- Midland, LL- Lowland*

The population density of the local bodies coming under the Pampa basin varies from 26 (Seethathode Panchayat) to 3786 (Alappuzha Municipality) and the average is 421/sq km.

Majority of the local bodies are in the population density range between 501-1500. Highland has the lowest population density (424) followed by midland (1122) and lowland (1554).

The major tribal groups residing in the upper basin include Malampandarams (major groups), Ulladas and Malayaras. The Malampandarams are the most primitive and nomadic tribe still pursuing a life of fruit and root gathering. Within the forested areas the largest human population is within the KFDC cardamom plantation, most of who are Sri Lankan repatriates. There are about 960 Tamil labours in the plantation. There are also KSEB staffs deployed at Kochu Pampa, Pampa, Kakki and Moozhiyar.

Major intervention in the river started in 1966 is the evolution of hydroelectric projects. There were 10 small and large dams constructed as part of the three major hydroelectric projects (Sabarigiri HEP, Sabarigiri Augmentation and Kakkad HEP) in the river. The dams were constructed at Kakki (1966), Anathodu (1967), Pampa (1966), Upper Moozhiyar (1979), Gavi (1990), Kal Ar (1990), Meenar I and II (1990), Veluthodu (1990) and Moozhiyar (1990) The actual reservoir area as per the KSEB estimate at FRL is 435 sq km. However, as per satellite image is only about 40 sq km. The tail race water of Sabarigiri Hydro Electric project for irrigation purpose. The tail race water is let into the river Kakkad and is picked up at Maniyar by a barrage. The water thus collected is diverted through a canal on the left bank of the river. There are also many lift irrigation projects associated with the basin.

The major importance of the area is associated with the Sabarimala temple located inside the Periyar Tiger Reserve. It is the site of the largest annual pilgrimage in the world with an estimate of between 17 million and 50 million devotees visiting every year. Thousands of devotees still follow the traditional mountainous forest path (approximately 61 km) from Erumely, believed to be taken by the Lord Ayyappa himself. The route starts from Erumely to Azhutha river, then crosses the mountain to reach Karivilam thodu. Then it cross Karimala from there to Cheriyanavattom, Valliyanavattom and finally reach Pampa Triveni. Then they have to climb Neelimala to reach Sabarimala temple. The *Thiruvabharana Ghoshayatra* is also going through this path.

The sheer beauty of the landscape, verdant forests, the number of reservoir water spreads, possibility of seeing wildlife especially in the grasslands, road access to the area and more than anything else the proximity to the well-established tourism destination. The Kerala Forest Development Corporation (KFDC) has developed an ecotourism facility at Gavi. Other major tourist attractions in the midland areas are also related to heritage and pilgrimage. The important locations in this area are Ayiroor-Cherukolpuzha and Aranmula. Aranmula is also

famous for the boat race (Uthrattathi Vallam kali). Tourist attractions in lowland area are mainly related to the *Kayal* tourism and boat race. The main destinations are Chambakulam, Kainakary, and Nedumudi. There are also many important pilgrim centres like Edathwa, Niranam, Chakkulathkavu etc.

The Pampa basin hosts valuable economic deposits of minerals used as common building materials like river sand crystalline rock, laterite and brick clay. The river sand mining activities in Pampa is routine activity for time immemorial. Before the ban of the sand mining in Kerala Rivers, close to 150 truckloads of sand are dug from the Pampa at Aranmula alone every day. This was a big business centred along nearly 100 km. of the stretch from Vadaserikkara to the day filled terrain of Kuttanad where we can see over 20 digging points. The statistics on the amount of sand removed from the river bed daily is not properly compiled. A study by NEERI (2003) showed that the annual clay consumption from the Pampa basin was 74250 MT. More than 600 labours were involved at that time in this activity.

Extraction of timber is main economic source of the forests for time immemorial. However, the ban on clear felling (1982) and selection felling (1986) reduced the possibility large scale timber extraction from the area. In addition to three major timber species (Teak, Rose wood and Anjili) , over 60 tree species are used to meet the requirements of plywood , matchwood, bobbin wood, pencil wood, packing cases, pulp etc. Reed extraction, included in the non-wood forest products. is one of the activities still continuing.

Apart from timber and reed 16 types of non-wood forest products (NWFP) are legally permitted to be collected through the Seethathodu Scheduled Tribe Service Cooperative Society. The highest quantum collected consistently is kunthirikkam (damar).

Another major activity in the forest area is the forest plantations. Gudarakal Range has the most extensive cardamom plantations in the public sector in Kerala. The entire stretch of forests on either side of the road from near Kozhikanam to Kochu Pampa has been converted to cardamom plantations. Cardamom plantation in the area started as a small venture by the Kerala Forest Department in 1969 over an area of 145ha near Pachakkanam. Later with Central Government funding this was expanded as a rehabilitation venture for Sri Lankan repatriates. In 1976 the management of the plantation was taken over by the Kerala Forest Development Corporation. The cardamom area was expanded to 1025ha. Currently only a portion of the area is under cardamom crop. The remaining areas which have been opened up have become degraded.

The Gudarakal Range earlier had more than 70sq.km. of its area in the grasslands managed as eucalyptus plantations. The Working Plan records the extent of teak plantations in the area as 65.66ha, Teak- Elavu plantations as 80.94ha and miscellaneous mixed plantation as 85.96ha. In addition failed eucalyptus plantations to the extent of 110ha are also recorded. So a total of 342.56ha of forests have been converted to some form of monoculture.

Major Environmental Concerns

Many studies have revealed that the river basin is currently subjected to acute pressure owing to rapid developmental activities and indiscriminate utilization of land, water and other resources. As a result, the system is being degraded at an alarming rate.

The APSF (2010) study has identified and ranked impact issues to be of importance in the Pampa Basin.

Nature of issue	Cause	ES	Light problem	Problem	Important problem	Very important problem	Major problem
A - SURFACE WATER RESOURCES - Pamba Basin							
Quantitative reduction of surface water resources - Pamba Basin							
Reduced availability	Impact from sandmining	81					
Reduced availability	Encroachment	72					
Water loss	Sedimentation of reservoirs	72					
Reduced availability	Abstraction for urban water supply	42					
Reduced availability	Long term climatic changes	30					
Reduced availability	Abstraction for rural water supply	28					
Pertubation of runoff	Infrastructures	27					
Reduced availability	Impact from upstream dams	18					
Reduced availability	Abstraction for irrigation	14					
Pertubation of runoff	Urbanisation	14					
Reduced availability	Short term variability of precipitation	14					
Water loss	Excessive evaporation	14					
Pertubation of runoff	Modification of soils	5					
Reduced availability	Abstraction for livestock	3					
Qualitative degradation of water quality resources - Pamba Basin							
Turbidity	Sandmining	72					
Pathogenic contamination	Excreta	63					
Organic pollution	Excreta	63					
Organic pollution	Urban waste	63					
Other pollution	Waste - plastic	54					
Pesticide pollution	Agricultural cropping	42					
Other chemical pollution	Urban waste	24					
Eutrophication	Agricultural cropping	12					
Turbidity	Erosion	12					
Organic pollution	Livestock	6					
Eutrophication	Excreta	6					
Other chemical pollution	Energy/transport	6					
B - GROUNDWATER RESOURCES - Pamba Basin							
Quantitative reduction of groundwater resources - Pamba Basin							
Reduced availability	Long term climatic changes	48					
Pertubation of infiltration	Urbanisation	18					
Reduced availability	Short term variability of precipitation	8					
Reduced availability	Abstraction for rural water supply	4					
Qualitative degradation of groundwater resources - Pamba Basin							
Pathogenic contamination	Excreta	81					
Organic pollution	Excreta	81					
Pesticide pollution	Agricultural cropping	7					

Fig. 3.2
Ranked impact issues affecting quality and quantity of water in Pampa (APSF, 2010)

The major issues which have direct impact on the quality and quantity of water available for various uses are: i) Sand mining, ii) Waste generated from Sabarimala pilgrimage, iii) Domestic/commercial waste disposal, iv) Agricultural residues, v) Forest degradation, vi) Quarrying, viii) Land use change, viii) Salt water intrusion, ix0 Encroachment, x) Unsustainable Tourism, xi) Clay mining and Climate change.

Conservation Initiatives

There are many studies conducted with regard to preparation of management plan for Pampa basin. The major initiatives for Pampa River are:

i. Pampa Action Plan, 2002.
ii. The Ministry of Environment, Forests and Climate Change (MoEFCCs) also allotted funds for pollution-abatement schemes in the Pampa in 2003 as part of the National River Conservation Plan (NRCP).
iii. The Pampa River Basin Authority Bill, 2009,
iv. Integrated River Basin Planning – Roadmap for Pampa by APSF (2010) and

Pampa Parirakshana Samithi is one of the major non government agencies working in the area to protect the River. Even though there are so many initiatives to conserve the river, none of them is having an integrated approach for conservation of the river by conserving the entire basin.

3.1.2. Periyar

Location and Geomorphology

The Periyar, the longest and largest among the 44 rivers of Kerala is popularly known as *the lifeline of Kerala*. The river has been performing a pivotal role in shaping the economic prospects of the state in terms of power generation, domestic water supply, irrigation, tourism, industrial production, collection of various inorganic resources and fisheries.

Periyar originates in the 'Sivagiri' group of hills in 'Sundara Malai' at an elevation of about 1830 m and is mainly enriched at four places during the course of its flow. Major portion of the Periyar River Basin is located in Kerala between 9°15'-10°20' N latitude and 76°08'- 77 °15' E longitude in the Idukki and Ernakulam districts (Pl.2). After about 48Km from its origin, it receives the Mullayar at Mullakudi in Kumily Panchayat. After Idukki reservoir, in between Chelachuvadu and Panamkutty (about 146 km from the origin), the Chinnar joins Periyar. Panniyar (also receiving water from Kallar) joins Periyar at Panamkutty, about 2 Km from the Chinnar joining area. Afterwards, Idamalayar (also receiving water from Pooyamkuttyar) joins Periyar near Bhoothathankettu (about 195 km from the origin). The other major tributaries joining the river on its course include: Perumthurayar, Kattapanayar, Anamalayar, Cheruthoniyar, Chittar, Kanjiyar, Karinthiriyar, Killivallithode, Kattapanayar, Melasseriyar, Muthirapuzha, Palar, Perinjankuttyar and Thottiyar. After Neriyamangalam, the river passes through Malayattur and thereafter taking a meandering course, the river reaches Aluva where it divides itself into two branches. The upper branch joins the Chalakudy River at Puthenvelikkara and then expands into a broad sheet of water at Munampam. The other branch taking a southern course is broken up into a number of small channels, which fall into the Vembanad Lake, adjoining the Arabian Sea The maximum width of the river is at

Kalady (405 m). The main tributaries contributing to the recharge of the river are present only in the highland regions of the basin.

Studies by PWD (1974, 1986), CESS (1984) and CWRDM (1995) shows the length of the river as 244 Km (in Kerala) and navigable length as 72 Km. However, length of Periyar in Kerala is recorded as 229Kms and the distance that the river flows through the plane is only 23 Km as per NEERI report (1992). The total drainage area recorded in almost all the studies is 5398 sq. km, out of this 5284 in Kerala and 114 in the Western slope of the Anamalai hills in Tamil Nadu (KSPCB 1981, 1985; PWD, 1986, CESS, 1984 and CWRDM, 1995). The entire Periyar water shed is divided into 183 sub water sheds and 448 micro water sheds. According to PWD (1974), the total runoff from the tributaries of Periyar amounts to 11607Mm3 of which 11341 Mm3 is the contribution from the catchments within Kerala. KSEB (2005) calculated the degree of flow regulation [ratio of total storage capacity (3.27 BCM) to long term mean average flow at the outlet (12.3 BCM)] as 25%. At about 130 km from the origin, the Idukki arch dam is constructed across the river which virtually cut off the river at this point, unless the Cheruthoni dam near the arch dam overflows.

The average rainfall in the basin area is 3000-3500 mm. The highland areas are receiving more rainfall (average 4000mm) compared to the midland and lowland regions. In most of the areas of the basin, about 60% of the rainfall is experienced during south west monsoon and 25% during north east monsoon period. The maximum rainfall was experienced in 1981 (3863 mm) and minimum in 1982 (2130mm). The mean annual temperature varies considerably from east to west (17.5^{o}C in Munnar, Kumily etc. to 27^{o}C in Kochi). In Munnar, the monthly mean temperature in January-February remains around 7^{o}C.

Major parts of the catchment area are hilly, undulating with a good number of waterfalls and valleys. Many areas are rugged with lofty peaks and precipitous slopes. The area in the Tamil Nadu region of the river has a catchment area spread over several peaks such as Chokkanpattimalai (1810m), Pachimalai (1860m), Kalimalai (1637m), Sundaramalai (1808m), Nagamalai (1733m), Komalai (1641m), and Vellimalai (2014m) on the Tamil Nadu border. The hilly tract of the river is rocky (crystalline) and of plutonic origin. There are occasional out crops of igneous and numerous boulders on the bottom of the stream beds and banks. The depth of the soil in the basin varies according to the terrain. 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 river has 17.85 sq.km. of clayey bottom, 28 sq.km. of

sandy clay bottom, 40 sq.km. of sandy bottom and 77 sq.km. of rocky- sandy bottom at various places in the basin. In the higher reaches, the sediments in the river show unmade sedimentation but in the lower reaches there is polymodal sedimentation. This suggests a single flow regime in the upper region and double and fluctuating flow regime of water in the lower reaches. During monsoon periods, the upstream of the river shows high suspended load (Anon, 1997).

Land use and Biodiversity

The vegetal cover classification of the Periyar basin shows that around 30% of the area is dense in vegetation, 50% medium (35-75%) and the remaining (<35%) is low in vegetation (Joseph, 2004). A good portion of the upper reaches of the basin is utilized for plantation crops like tea, coffee, cardamom and rubber. The major share of the cardamom and tea production in the state is from this region. The maximum coverage of dense forest in the state is also occupied by the study area. Major crops being cultivated in the river basin includes rice, coconut, areca nut, banana, rubber, vegetables etc. The area under non-agricultural use is mainly water bodies, dwelling units and industrial areas. The steep sloping lands, barren crystalline area, highly undulating upland area and unutilized degraded forests are included in the category of wastelands. In the midland region, the main cultivations are paddy, mainly along the flood plains, coconut and other mixed crops along the valley portions and mainly rubber along the mounts and hill slopes. In the lowland region, the main cultivations are paddy, coconut and other mixed crops (Joseph, 2004).

CED (2010) has analysed the land use of the basin in midland and lowland regions. The land use map prepared using the IRS-LISS III images gives the various land use classes in highland and midland area. In the highlands about 56% of the area is under forests/forest plantation whereas it is only 36 % in the midlands. (Table 3.4).

Table 3.4
Comparison of Land use in Highland and Midland (Area Sq.km.)

Land use	Highland		Midland		Total	
	Area	%	Area	%	Area	%
Built up area	47.3	1.2	43.3	6.6	90.6	1.9
Paddy/lowland agriculture	2.9	0.1	37.2	5.7	40.1	0.9
Homestead plantation	855.0	21.1	325.0	49.8	1180.0	25.1
Commercial plantation	862.0	21.3	1.9	0.3	863.9	18.4
Forest	1882.0	46.5	123.0	18.8	2005.0	42.6
Forest plantation	250.0	6.2	109.0	16.7	359.0	7.6
Water body	149.8	3.7	13.8	2.1	163.6	3.5
Total	**4049**	**100**	**653.2**	**100**	**4702**	**100**

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. The forests and forest plantations are areas which contribute much to the health of the river. A good percentage of this area is in the highland.

There is no single flora published for the districts coming under the basin (Idukki and Ernakulam) The first botanical collection from Idukki district was made by Beddome in 1882 from Peerumedu and adjacent Anamudi, which were part of the erstwhile princely state of Travancore (Vivekananthan, 1981). Barnes, Beddome, Bourdillon, Meebold and Venkoba Rao made collections in the late 19th century and early 20th century and their collections were cited by Hooker (1872-1897) and Gamble and Fischer (1915-1936). Barnes (1939) dealt with the Gesneriaceae of High Ranges. Sebastine and Vivekananthan (1967) and Shetty and Vivekananthan (1971) published brief accounts on the flora of Anamudi and Devikulam. Vivekananthan (1978) dealt with the vegetation of Periyar Tiger Reserve and also listed out 12 rare and threatened plants. Studies by Shetty and Vivekananthan (1968, 1969, 1970, 1973, 1975); Sharma et al (1974); Nayar (1974); Sreekumar et al (1983a, 1983b); Nair and Sreekumar (1985); Pandurangan and Nair (1995) resulted in the discovery of new taxa from the district. Among the new taxa, Cassia intermedia and Gomphostemma keralensis were from the Periyar Tiger Reserve. Shetty and Vivekananthan (1972) reported the occurrence of some rare and little known taxa. Nagendran et al (1976-77) and Bhaskar and Razi (1978) made collections of Podostemaceae and Balsaminaceae. Mohanan et al (1984) reported some rare and interesting plants from the Idukki Hydroelectric Project Area. Balasubramanyam et al (1989) listed out some of the plants from the proposed Pooyamkutty Hydroelectric Project Area. Sasidharan et al (1996) provided an account of Cryptogamic and Phanerogamic flora of the Medicinal Plant Conservation Area in the Eravikulam National Park. The flora of Periyar Tiger Reserve (PTR) was studied in detail by Sasidharan (1998) during June 1993 to September 1997 and described 1965 taxa. Dicotyledons dominate with 1440 species in 613 genera under 137 families. Monocotyledons are represented by 525 species in 210 genera under 22 families. Poaceae with 168 species among monocots and Fabaceae with 155 species among dicots are dominant families. Among the 159 families, 28 dicot and 6 monocot families are represented by single species each. Among the 1272 species that are considered endemic to the Southern Western Ghats, 515 species were collected from the Tiger Reserve. During the study 150 species that have been placed under various threat categories could be collected. These include 17 species categorised as ‘possibly extinct.

Jomy Augstine (2001) also studied the angiosperm flora of Periyar Tiger Reserve of the district.

The flowering plant diversity of Mathikettan shola national park was attempted by Jomy Augustine (2002). He also explored floral diversity Cardamom Hill regions of the Western Ghats and recorded 1,044 species of flowering plants (Jomy A, 2012). Of which, 395 are endemic to southern Western Ghats and 38 rare or threatened. At 39 percent, the degree of endemism is higher than any other forest areas in Kerala, signifying its ecological uniqueness. This study also recorded 20 species of Impatiens of which 16 are endemic to southern Western Ghats while also revealing the presence of 5 species of plants previously considered "Possibly Extinct" (Jomy A, 2002).

Certain studies on Mangroves (Anupama & Sivadasan, 2004), Sacred groves (Induchoodan et al., 1991) and forest area of the district (Sivadasan et al., 2001) adds to the floristic knowledge of Ernakulam district

Contribution towards the vascular flora of Eravikulam (part of Periyar Basin) was done by Karunakaran et.al (1998). Idukki district flora was completed by Botanical Survey of India, Coimbatore long back in 1980's, but is not yet published. The grass flora was studied by Sreekumar and Nair (1991). The floristic details of the area are also available from the ancient work of Gamble and Fischer (1915-1936) and a recent enumeration of Kerala Flora by Nayar et.al (2006). An assessment of the ecological status of the river mainly based on earlier studies was attempted recently by Smakhtin et.al (2007), in connection with developing common procedure for assessment of ecological status of Indian River Basins in the context of environmental water requirements. Recently, Sunil (2015) has studied the Flowering Plant Diversity of Ernakulam District.

However, there is no concentrated effort to enumerate the riparian flora of Periyar. The studies mentioned above like Sunil (2015), Jomy (2002 and 2012) Sasidharan !998) etc. has listed the riparian species also. In addition, Jomy Augustine and his students have done a good number of unpublished taxonomic studies in the Riparian regions of Periyar in Idukki district from 2010 onwards.

Studies on faunal biodiversity of the area are restricted to certain groups only. Fishes and butterflies are the most studied among them. That too is mainly restricted to the Periyar Tiger Reserve. Jafer et. al (1997) reported 119 species. Maximum number of species recorded belonged to Nymphalidae (29 spp.) followed by Pieridae (18 spp.), Satyridae (18 spp.), Hesperiidae (14 spp.) and Lycaenidae (13 spp.). A survey was conducted in the Periyar Tiger

Reserve by Andrews et.al. to enlist the amphibian fauna and their microhabitats and status. A total of 25 species belonging to 5 families were recorded. Of these, 2 species are abundant, 11 species common and the rest are rare in the region. Forty five species of reptiles including two species of testudines, 13 species of lizards and 30 species of snakes have been recorded in PTR by Zacharias (1997). The grasslands of PTR are ideal habitats for endangered species of fauna like Nilgiri Tahr, Nilgiri Pipit etc.

Chacko (1948) enlisted the fishes of Periyar Lake. Reservoir fishes of India were studied by Sugunan (1995) which included Periyar also. A study by Arun (1998) revealed the distribution of 56% of the endemic fishes of Kerala in the Periyar lake and river system which makes it a unique and diverse Icthyo faunal region in South India. The study also revealed the disappearance of 16 species of fishes from the aquatic system within a span of 50 years, which include Eels, Catfishes, Goby and Cyprinides. Arun (1998) Ponniah and Gopalakrishnan (2002), under the auspicious of NBFGR, listed all the 287 fresh water species of fishes found in Western Ghats including those in Periyar waters. A complete systematic list of the fishes of Cochin backwater and their frequency of occurrence was presented by Kurup (1982). Kurup and Samuel (1987) observed 89 species of marine fishes in Cochin backwaters of which 41 species were euryhaline and 48 steno haline. The scientific literature on different trophic communities pertaining to cochin backwaters like Wood Borers (Nair,1994), Biofoulers (Menon and Nair, 1967;Menon ,1971; Meenakumari and Nair,1994), Bivalves(Salih,1977; Nair,1985; Kattickaran,1989; Sreedhar,1991), Meico and Micro fauna(Jayasree,1971; Sunilkumar,1995) are available. The biodiversity status of the fishes in the river system was enumerated by Arunachalm (2000) and Kurup et al (2001). The study by Kurup, et.al. (2001) identified 31 species (16 food fish and 15 ornamental) of fishes from Periyar River, of which five of them are critically endangered. The fish species *Labeo ariza* is restricted only to this river. The study suggested special conservation measures to Periyar river system because of the presence of five endemic and critically endangered species at its upstream region.

Socioeconomic profile

The Periyar river basin covers 90 local bodies (BMCs) in Idukki (37), Ernakulam (51) and Thrissur (2) districts. The distribution of the local bodies in various physiographic regions is given in Table 3.5.

The main Periyar River flows through 56 local bodies (16 in high land including , 13 in midland and all the 27 in lowland) The entire Idukki district and north eastern part of

Ernakulam district with 39 Grama Panchayats (35 in Idukki and 4 in Ernakulam) constitute the highland.

Table 3.5
List of Local Bodies in PRB

Sl. No.	Local body	Sl. No.	Local body	Sl. No.	Local body
Idukki Dist.					
1	Kumily (HL)*	14	Mariyapuram(HL)	27	Chinnakkanal(HL)
2	Vandiperiyar(HL)*	15	Kamakshy(HL)	28	Devikulam(HL)
3	Peerumedu(HL)	16	Vathikudy(HL)*	29	Munnar(HL)
4	Elappara(HL)*	17	Idukki-Kanjikuzhy(HL)*	30	Mankulam(HL)
5	Upputhara(HL)*	18	Udumbannur(HL)*	31	Konnathadi(HL)*
6	Ayyappankovil(HL)*	19	Karunapuram(HL)	32	Vellathooval(HL)*
7	Chakkupallam(HL)	20	Pampadumpara(HL)	33	Bison Valley(HL)
8	Vandanmettu(HL)	21	Nedumkandam(HL)	34	Pallivasal(HL)
9	Kattapana(HL)	22	Udumpanchola(HL)	35	Adimali(HL)*
10	Kanchiar(HL)*	23	Senapathy(HL)	36	Karimannur (HL)*
11	Erattayar(HL)	24	Rajakumari(HL)	37	Vannappuram (HL)*
12	Arakulam(HL)*	25	Rajakad(HL)		
13	Vazhathoppu(HL)*	26	Santhanpara(HL)		
Ernakulam Dist.					
38	Kuttampuzha(HL)*	55	Perumbavoor Municipality(ML)*	72	Chendhamangalam (LL)*
39	Kavalangad(HL)*	56	Sreemoolanagaram (ML)*	73	Kottuvally(LL)*
40	Keerampara(HL)*	57	Vengola (ML)	74	Vadakkekara(LL)*
41	Ayyampuzha(HL)*	58	Vazhakkulam(ML)*	75	Ezhikkara(LL)*
42	Pindimana(HL/ML)*	59	Keezhumadu(ML)*	76	Chittattukara(LL)*
43	Kottapady(HL/ML)	60	Edathala(ML)	77	Paravur Municipality(LL)*
44	Vengoor(HL/ML)*	61	Nedumbassery(ML)*	78	Mulavukad(LL)
45	Mudakkuzha(HL/ML)	62	Chengamanadu(ML)*	79	Pallipuram(LL)*
46	Malayattur-Neeleswaram(HL/ML)*	63	Aluva Municipality(ML)*	80	Kuzhupally(LL)*
47	Asamannur (ML)	64	Choornikara (LL)*	81	Edavanakad(LL)*
48	Koovappady (ML)*	65	Kunnukara(LL)*	82	Nayarambalam(LL)*
49	Okkal(ML)*	66	Puthenvelikkara(LL)*	83	Njarackal(LL)*
50	Kalady(ML)*	67	Karumaloor(LL)*	84	Elamkunnapuzha(LL)
51	Mukkannur(ML)	68	Varappuzha(LL)*	85	Cheranelloor(LL)*
52	Karukutty(ML)	69	Alangadu(LL)*	86	Kadamakudi(LL)*
53	Angamaly Municipality(ML)	70	Eloor(LL)*	87	Kochi Corporation(LL)*
54	Kanjoor(ML)*	71	Kadungalloor(LL)*	88	Kalamassery Municipality (LL)*
Thrissur District					
89	Kodungallur MPTY (LL)*	90	Eriyad(LL)*		

**Main river passing LBs HHL-High Highland, HL-Highland, ML- Midland, LL- Lowland*

The middle and south east portion of Ernakulam district with 22 Grama Panchayats and 3 municipalities comes under the midland area. The lowland area forms the western region of

Ernakulam district with 22 Grama Panchayats, 2 municipalities and one city corporation and south west portion of Thrissur district with 1 municipality and 1 Grama Panchayat.

The distribution of population shows noticeable variation with respect to physiographic region. The density of population and households is very high in lowland areas, whereas it is very low in highlands (less than 5% of the lowland). The population in PRB also include tribes. The tribal population inhabit in the upland areas, mainly in the Idukki district. The major tribal groups are Malayarayans, Urali, Muthuvans, Hill Pulayan, Pulayan, Ulladan and Kadar. At present, the tribal population of the Periyar catchment area are subjected to economic, social and cultural changes due to various factors, the most important being those associated with extensive plantation and development of hydro electric projects. As a result, the culture and civilization of the tribal population became influenced by the traits prevailing in other parts of the state.

The livelihood of the majority of population in the Periyar Basin is dependent on the resources from the area. The resource dependency also shows much variation with respect to the three physiographic regions. The major economic activities with local resources in the highland areas includes: i) Large plantations like Tea, Coffee and Cardamom, ii) Small scale gardens of Coffee, Cardamom, vegetables etc, iii(Collection of non wood forest products, iii) Cottage industries based on forest/riverine products, iv) Hydroelectric projects and Eco/Farm tourism. In midland areas the major activities are: i) Agriculture (irrigated/non irrigated paddy cultivation, coconut based mixed crops, vegetables, Banana, Pineapple etc.), ii) Rubber Plantation, iii) Homestead planting (Rubber, Coconut, Cocoa, Myristica, vegetables etc.), iv) Cottage industries based on forest products (mainly Bamboo based), v) River sand mining, vi) Small industries like bricks, tiles, and quarry based products, rice mill, curry powder, bone meal, metal industries etc. and vii) River bank tourism. In the lowland the main economic activities includes: i) Marine and coastal fishing, ii) Estuarine fisheries and Aquaculture , iii) Paddy (Pokkali) cultivation, iv) Large industries (fertilizers, insecticides, chemicals etc.) and v) Backwater tourism.

The entire water needs of the basin are met by the river. There are 48 water supply schemes (including the ongoing/proposed schemes) covering 89 local bodies situated in PRB. The projected water demand for domestic and livestock purposes is 349.4 Mm^3 and 21.8 Mm^3 respectively (NEERI, 2003).The major water supply scheme in Aluva with the assistance of World Bank, supply water to the Kochi Corporation, Aluva and Paravur Municipality and

Keezhumad Panchayat. The plant erected in 7 Ha of land has a treating capacity of190 million litres/day.

The highest numbers of hydroelectric projects are associated with this River. There are hydroelectric projects presently functioning in upland areas of Periyar (Table 3.6). More than 60% of the hydal power generated by KSEB in Kerala is from the Periyar River.

Table 3.6
Power generation from Periyar

Sl. No.	Name of Project	Name of river/major tributary	Energy (M units)
1	Idukki	Periyar, Cheruthoni and Killivally	2398
2	Pallivasal	Muthirapuzha	284
3	Mattuppetty	Muthirapuzha	6.4
4	Shengulam	Muthirapuzha	182
5	Neriyamangalam and Neriyamangalam Extension	Muthirapuzha	309.6
6	Panniyar & Panniyar Augmentation	Muthirapuzha	158
7	Lower Periyar	Muthirapuzha	493
8	Idamalayar	Idamalayar	320
Total			**4151**

In addition, there are about 80 major irrigation projects and innumerable number of smaller projects supplying water to various types of agriculture to an approximate area of 35,000 ha. The major irrigation project in Periyar River is the Periyar Valley Irrigation Project (PVIP), which is one among the biggest projects in Kerala. This project envisages the utilization of tail race water from the hydal schemes in Muthirapuzha, a tributary of Periyar, together with the controlled releases from Ennakkal dam across Idamalayar. Out of the two canal systems of the project, the right bank canal system is known as Idamalayar Irrigation Project and the left bank canal system is Pampa Valley Irrigation Project. The barrage is constructed at Bhoothathankettu for both projects. The project aims to achieve the stabilization of first and second crop (*Virippu* and *Mundagan*) in an area 53,000 ha (20200 by Idamalayar and 32,800 by PVIP). The scheme is also assumed to sufficient discharge (above 28.32 m^3/sec.) into the river for arresting the increase of salinity in the lower reaches as well as catering the industrial and domestic water needs of the Greater Cochin area.

The fresh water of Periyar has always been very rich in fish life. However, freshwater fishes in rivers and reservoirs are not sustainably used for livelihoods. The lower reaches is well known for easy availability of various types of tasty fishes and a variety of shell fishes which includes crab, prawn, "*Konchu"* and so on. Here, fishing is still one of the important

occupations of the people on its banks. The famous 'Chinese net' is still a common sight in the estuarine regions of the river.

The river sand from Periyar is an extensively used material in the booming construction sector. The local bodies on the banks of Periyar earn a substantial part of the revenue by auctioning sand removal rights. The mining activity was entrusted to Grama Panchayats and the sale is done at prices fixed by District Collector. At least 5000 people are directly engaged in the removal of sand from Periyar and about 10 times that number depend on Periyar sand for their livelihood through construction activities. Large quantity of clay was mined from the paddy fields in the midland for manufacturing tiles and bricks. Another activity is granite quarrying which is also prevalent in many areas of the basin.

Major non timber forest products include bamboos, reeds honey, black dammar, "*incha*" (soap bark from *Acacia caesia* (L.) Willd. Etc. One major livelihood activity of the people in the basin is Bamboo Mat weaving. Collection of Bamboo poles (*Ochlandra* travancorica) from the forest and its distribution is now controlled by the Kerala State Bamboo Corporation. Periyar Tiger Reserve is the largest protected area in Kerala State, with more than 60% tropical evergreen forests, which is the ideal habitat of the black dammar tree, *Canarium strictum* Roxb. of family Burseraceae. There are more than 400 people belong to the places of Sivagiri, Davadanam, Daivapatanam, Chokkampetti and Kumily, engaged in black dammar collection.

The Koovappady to Kochi stretch of the River is the main industrialized zone of the Periyar river basin. Koovappady to Aluva stretch mainly consists of medium sized industries like Rice mill, bone meal, plywood, rubber processing units, curry powder and other food products etc. A cluster of chemical and other industries are established on the banks of the river after Aluva mainly at Udyogamandal in Eloor Panchayat. The industrialization began with the establishment of M/s FACT in 1947. Now there are over 50 large and medium industries and over 2500 small scale industries in this region. M/s Indian Rare Earths, M/s Travancore Cochin Chemicals, M/s Binani Zinc Ltd, M/s Cochin Minerals and Rutales, M/s Indian Aluminium Company, M/s Hindustan Insecticides and M/s Carborundum Universal etc., are some large scale factories in this area. The major produces from the industries in this area are fertilizers, pesticides, chemicals and allied industries, petroleum refining and heavy metal processing, radioactive mineral processing, animal bone processing units, battery manufacturers, mercury products, acid manufacturers, pigment and latex producers etc. The

industries also consume large quantity of water from Periyar. The water used by the industries in the Kochi belt is approximately 1844 mm^3/day.

Many areas in River Basin are famous for tourist attraction. The mountain ranges where Periyar originates and the serene beautiful lakes reflecting the nature around along with forest abounding and attractive wild life are major attractions to the tourists. The Periyar Lake with boating facilities, the Bhoothathankettu reservoir and beautiful Thattekad bird sanctuary adjacent to it attracts nature lovers and tourists from all over the world. The Periyar Tiger Reserve, Idukki Wildlife Sanctuary, Munnar tourist area, Eravikulam National Park, Idukki Reservoir, Kodanad Elephant Kraal, the famous Malayattur church, the birth place of Adisankara (Kalady), Sivarathri Manalpuram (Aluva), the estuaries in the downstream (Kochi) etc., are all spots of natural beauty along the banks of Periyar.

Major Environmental Concerns

A critical study by CED (2010) from the 64 local bodies (39 in highland and 25 in midland) in the study area shows that the river basin is currently subjected to acute pressure owing to rapid developmental activities and indiscriminate utilization of land, water and other resources. As a result, the system is being degraded at an alarming rate, especially in the midlands. The floodplains of the river in midland region which once served as water storage regions are now in the verge of complete destruction or exploitation. The undesirable input of residues exceeding the assimilative capacity of this fragile ecosystem is now increasingly resulting in various kinds of pollution and eutrophication. Encroachment and reclamation of floodplains for various activities along with unauthorized occupation is still a major problem in the basin area. 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.

The pollutants that adversely affect the natural environmental quality of the water in the river include toxic and hazardous materials such as heavy metals, phenolics, hydrocarbons, pesticides, radionuclides, ammonia, phosphates, domestic and untreated waste water etc. The main reason for contamination of the river water is dumping waste materials from various sources, dead animals, plastic and domestic wastes. In addition to this agricultural runoff from paddy fields carry huge amounts of water hyacinth, grasses, pesticide and insecticide residue etc. The floating materials at large pose physical obstruction to bathers, navigators and

fisherman. Pollution of water body is present in both highlands and lowlands. However, the intensity is high in the midlands. The major sources of pollution are: i) Solid and Liquid Waste from houses and commercial establishments, ii) Slaughterhouse and Poultry Waste , iii) Hospital Waste, iv) Leachate from agriculture land, v) Industrial waste and iv) Pollution occurred due to the Tourism and Pilgrimage

Large quantities of solid and liquid wastes are generated in the local bodies in the highland and midland of PRB which ultimately reaches the river. The solid wastes, both degradable and non degradable, are found deposited at several places especially in towns and junctions. There are 95 such centres identified by CED study (2010), 57 in highland and 38 midland, which generate more than one ton of solid waste/day. The total quantity of solid waste generated in public places at that time is estimated as 211 ton/day (105 from highland and 106 from midland). There are 30 local bodies (13 in highland and 17 in midland) which generate more than 3 tons of waste/day in public places. Nearly 30% of these wastes are recyclable plastic and glass materials. However, none of the local bodies have a full proof solid waste management system.

The main sources of liquid wastes are from housing colonies and commercial establishments like hotels, restaurants etc. The major liquid waste generation locations in the basin are Kattappana, Kumily, Vandiperiyar, Munnar, Santhanpara and Adimali. Kalady, Angamaly, Perumbavoor and Aluva etc. Major housing colonies which discharge large quantities of waste water into the River/Stream include Mali colony in Vandanmettu Panchayat, Kajanapara colony (Rajakumari), Rosapookandam colony (Kumily), Munnar colony (Munnar) etc., The "*Layams"* associated with the tea estates in the highland also generate large quantity of solid and liquid waste.

One major source of pollution in Periyar River is slaughterhouse waste. Slaughtering of animals generates wastes consisting of non edible offal (like lungs, large intestines, various glands, animal tissues, organs, various body parts, etc.) stomach/intestinal contents, dung, bones, etc. Large quantity of waste water is also generated during washing. All these are directly discharged in to the river. The average quantity of unusable wet solid waste produced by slaughtering (excluding dung) is estimated as12 kg per cattle/buffalo, 4 kg per pig, 2.5 kg per goat, and 0.6 kg per poultry. The present practices in most of the slaughter sheds and chicken stalls are to dispose the wastes to the rivers or streams. Almost all the bridges and culverts in the PRB are the potential sites for throwing slaughter and poultry waste during night time. The overall responsibility of management of the slaughterhouse is vested with the

respective local bodies but none of the local bodies have any proper slaughtering facility. There are many illegal slaughtering places in most of the Grama Panchayats and Municipalities which has been creating pollution problems, especially pollution of the river due to dumping of waste.

The CED study (2010) has given details of hospital waste generated and disposed to the River, quantified the pollution from intensive agriculture practicing areas and details of industry based pollution. One major industry in the banks of Periyar is the rice mills which consume large quantity of water and generate waste water also.

There are many ponds and lakes in the floodplains of midland region. These ponds and lakes are serving as water storage and recharge areas. In addition to many independent water bodies (ponds) situated in the periphery of the paddy fields, there are many peculiar water bodies with considerable area, present along with the streams in the midland. Locally these water bodies are named as "*thura*" or "*chal"*. These water bodies serve as major source of water for drinking, bathing and irrigation. Present condition of these water bodies is very pathetic. Eutrophication is high and are infested with weeds like *Cyperus* sp. *Eichornia crassipes, Salvinia molesta* etc. The main reason for the clogging of water bodies are:


Clogged Water Body: Thottichira - Koovapadi GP

I. Siltation and leachate from the agricultural land in the catchment,
II. Discharge of solid and liquid waste from modern rice mills, saw mills, rock crusher units, food products units etc. and
III. The absence of flooding.

Though sand mining can be allowed to a certain level from the rivers taking in to consideration of the carrying capacity, it was reached alarming situation in the Periyar River and created serious imbalance on the morphology of river and consequent environmental threat. Detailed studies on sand mining in Ernakulam district was conducted by CESS (2002

& 2005). According to the study, the riverbed lowering in Periyar, estimated for period 1980-2000 (20 years) is 3.73 m.

Till 1870s the hill tract in the Idukki District where the river originates, was covered with thick forest. The catchment areas of Periyar first saw degradation during last decades of 19th century, when the colonial rule embarked on the idea of plantations in Munnar, Kattapana, Elappara and Vandiperiyar. This resulted in massive tree felling in forest area and the conversion of forest land to tea, coffee, rubber, teak and cardamom plantations. Many type of development activities like roads, buildings etc., were also implemented during these period, leading to urbanization and population explosion. This was followed by establishment of large scale cardamom plantation leading to its naming as Cardamom Hill Reserve (CHR) in 1897.

Construction of dams was started in 1876 which led to loss of natural forests in many regions. These developments with consequent improvements and projects like Pallivasal HEP, Idukki HEP, Panniyar HEP, Shengulam HEP, Idamalayar HEP, Bhoothathankettu IP etc., were implemented at a great ecological cost of deforestation of prime evergreen forests. The shola in the High ranges are home to a wide variety of unique flora and fauna and many streams originate from this area. The damages to the shola have already proved detrimental to Nilgiri Tahr, a highly endangered species of the Nilgiri Biosphere. After the Second World War, the "grow more food" campaign, by the state, further accelerated the process of deforestation by diverting large areas of forest land for agricultural purposes. This has resulted in a heavy influx of migrants.

Forest fires, often created artificially in the inner dense area of the forest, are also caused deforestation. These areas are later utilized to illegal cultivation of narcotics like *Ganja* and the benefits are reaped by the encroachers. This is a major threat to the rain forest of Pooyamkutty and Idukki catchment areas.

It is a common feature on the banks of Periyar that the agricultural pattern has been changed alarmingly over last ten years. The paddy cultivation has been replaced with plantations and seasonal tapioca cultivation. This has resulted in heavy soil erosion and drying up of the banks.

The CED study (2010) also noticed that the River bank encroachment is a common practice in the entire length of the river. Approximate length of the bank occupied by the encroachers is estimated to be 140 kms on both sides. Some areas are occupied by settlers while other parts are utilized for cultivation of seasonal crops. Encroachment in the catchment area is alarmingly high in the Idukki district. After the construction of Idukki dam the flow of river is

completely cut off in the downstream for a length of approximately 20 kms. The original breadth of the river valley before construction of the dam was above 100m. Now it has been reduced to less than 3 m. All these activities resulted in the deforestation and consequent erosion of the river banks, drying up of streams, silting in dams and endangering of valuable flora and fauna. This ultimately leads to the depletion of catchment water to the river.

Another major issue in the River which has high environmental impact is the tail water diversion. The main origin of the river flow from the Sivagiri group of hills is virtually cut off by Idukki Arch dam and Cheruthoni dam and no water flows down unless Cheruthoni dam overflows. For the power generation the water is diverted to Kulamavu dam from where it is tunnelled down to Moolamattam station. The tail water is then diverted to Muvattupuzha River which empties into Vembanad estuary. The tail water from Pallivasal project is utilized in Shengulam which ultimately joins with that of Panniyar project and is dammed up in Kallarkutty. The tail water from Neriyamangalam project comes to Lower Periyar which merges with that from Idamalayar project and is impounded in PVIP. The direct impacts due to diversion of tail water are: i) hindrance to the original flow of the river, ii) massive encroachment on the banks, iii) loss of riparian biodiversity, iv) reduction in the water discharge to the lower reaches of river (reduced flow) thereby increasing the saline water incursion, and v) the low river discharge rate is insufficient to the effective dilution of the waste water received in the industrial zone. The traditional water users of the river are not able to use the water for bathing, religious purposes etc. All these created problems to the social life of the people living in the area.

Tourism, especially the pilgrim tourism is another area which is having high impact on the River ecosystem. Poor sanitation facilities in the tourist centres coupled with heavy inflow of tourists lead to pollution of the river, especially during Sivarathri days (about 1.5 lakh people crowd in Aluva and Kalady). Malayattoor is recently declared as an International shrine for pilgrim tourism. Since there is no restriction on tourists invading in the forest areas during the pilgrim seasons, unaccountable damage is reported to flora and fauna. A study by KSCSTE (2009) reported high Palmer's Algal index values during different seasons. This indicates high organic contamination at this station. It supports the presence of most pollution tolerant genera like Ankistrodesmus, Scenedesmus, Oscillatoria, Anabaena, Synedra and Navicula and Rotifer like Philodina, a pollution indicator. Marcella, a pollution tolerant form is also reported. The presence of organic pollution tolerant family Chironomideae also shows the quantity of organic pollution. During the Sabarimala pilgrim season, more than 3 lakh people use the river under the bridge at Vandiperiyar which create organic pollution. Other major

pilgrim centres are Malayattur Church and Thiruvairanikulam temple in Sreemoolanagarm Grama Panchayat

The pollution, overexploitation and other interventions in the catchment and river mentioned earlier has caused serious and far reaching consequence to the ecosystem, which include:

I. Clogging of water bodies and chances for emission of more green house gases,
II. Diminution of resources like sand, fish etc;
III. Loss of biodiversity and critical species;
IV. Reduction in agriculture production and productivity
V. Waterborne and zoonotic diseases;
VI. Food toxicity;
VII. Slumping of river/stream banks;
VIII. Scarcity of drinking water;
IX. Soil erosion;
X. Decrease in agricultural production and productivity,
XI. Loss of areas for socio-cultural activities, and
XII. Depletion of aesthetic value.

2.2.4 Conservation Initiatives

There are many initiatives to protect the river at Government and community level. The Kerala State Pollution Control Board has initiated Periyar action plan- phase1- status survey and project identification (KSPCB, 1981). Most of the activities of these initiatives address only one issue that is pollution from industrial sector. However, due to the lack of an integrated approach, the action is not completed. The major non Government organization associated with the protection of the river is the "*Periyar Samrakshana Samithi"* which has undertaken various studies and other initiatives with people participation.

3.1.3 Chalakudyar

Location and Geomorphology

The Chalakkudy River Basin lies between 10^0 13' to 10^0 55' North latitudes and 76^0 25' to 77 Eastern longitudes in the Anamalai landscape unit of the southern Western Ghats immediate south of the Palgaht Gap (Pl. 3). The river originates from the north-western part of the Anamalai hills and flow westward to reach Lakshadweep Sea near Kodungallur in the west. The river basin is bounded by the Karuvannur and Bharathappuzha river basins in the North, upper catchments of Bharathappuzha River and Anamalai of Tamil Nadu part in the East, Periyar basin part of Anamalai, Idamalayar-Pooyamkutty valleys in the South-East, Lower plains of Periyar River in the Ernakulam in the South and Lakshadweep Sea near the Kodungallur coast in the West. It is the fifth longest, sixth largest by catchment size and eighth high yielding river in Kerala. It has an average length of 144 km and the total drainage

area covers 1704 km^2 in the Thrissur, Ernakulam and Palakkad districts of Kerala (1404 km^2) and Coimbatore district (Valparai part) of Tamil Nadu (300 km^2) (GoK 1974).

The Chalakkudy River is a 6th order stream and the main tributaries are of 5th order. First Sixth order river is formed when the Kuriyarkutty tributary and the Parambikulam tributary confluence at Kuriyarkutty and all the other tributaries (5th order) joins to the main downstream to this point. So physiographically the river from the Kuriyarkutty downwards should be considered as the Chalakkudy main river. The Sholayar originating from the Akkamalai-Grass hills region near Valparai in Tamil Nadu in the North Western part of Anaimudi and Eravikulam plateau, The Parambikulam tributary originating from an arc shaped eastern high elevation ridge between Perukundru-malai (1733 m) and Umaya Malai (1250 m) and Vengoli Peak (1128 m) in the North-west part of Sholayar-Valpaarai plateau. The Kuriyarkuttyar tributary originates from a narrow South-West valley between the 1300 m elevated South-Eastern part of Nelliyampathy hills and 1290 m Pandara Varai and the low elevated Top slip area (750 m) in between Panadaravarai and Perukundru malai-Vengoli ridge separating the Parambikulam Valley. Karapara tributary originates exclusively from the south western slopes of Nelliyampathy hills (Bachan 2010, Bachan et al., 2014).

The Chalakkudy river basin composed of distinctive four levels in its catchments based on the area of the height classes, (i). Highly elevated plateaus of >1000 m in the Malakkapara-Valparai region in the southern boundary (adjacent to Anaimudi-Eravikulam plateau) and the Nelliyampathy plateau in the northern boundary of the basin (adjacent to the Palgaht Gap); (ii). A unique medium elevation (500-600 m) plateau in the Kuriyarkutty-Parambikulam sub-basin in between the Valparai-Nelliyampathy plateaus; (iii). Slightly ascending zone from the (200 m) Vazhachal region to the (500 m) medium elevation area and (iv). The lower plains 0-100 m elevation from the Athirappilly downstream to the Chalakkudy plains and up to the river mouth. (Bachan et al., 2014)

Details regarding the geology of the area are available in the Geological and Mineral Map of Kerala (Balasundaram 1970) and soil characters obtained from soil map (Krishnan et *al.* 1996). The main rock formations in the Chalakkudy River Basin consists of crystalline rocks of Achaean-Pre Cambrian era (2600 million years old) mainly charanockite, and biotite gneiss, hornblende gneiss and migmatitic gneisses. There is intrusion of granites (acidic rocks) mainly in the Parampikulam and Nelliyampathy plateaus. The terrain has undergone an earlier plastic deformation phase which resulted in an intense folding with axes tending north west- south east to east west direction and a later brittle deformation phase which resulted in a

number of lineaments and fractures. Many tributaries and various sections of mainstream are apparently controlled by lineaments and fractures (CESS 2003).

The Anamalai landscape unit comes under high rainfall region of the Western Ghats and represented with one of the largest extent climax wet evergreen forests in the southern Western Ghats. But the particular warmer physiography of the Parambikulam plateau make the climatic regime of the basin much complex. The river basin receives a 3300 mm rainfall annually. Of which higher rainfall is received in the upper catchments of Sholayar (> 4000 mm), then Karapara (> 3500 mm), Poringal (> 3500 mm) Chalakkudy main river and the least in the Thellikkal section of the Parambikulam sub basin (1342 mm) Bachan et al. (2014). Major part of rain obtained during the south-west monsoon period (June – September), followed by north-east monsoon (December – March) and intermittent inter-monsoons during October-November and April-May.

The average mean temperature of the basin is 22.2 ^{0}C and that is highest for Parambikulam sub basin 23.3 ^{0}C and lowest for Sholayar sub basin. Since the vegetation of an area is limited with the climate of the region, with in a monsoonal subcontinent with a high average rainfall the mean temperatures of the coldest months and length of the dry months are critical. The temperature gradient is linked to elevation and it has been estimated that the decrease in temperature is almost 0.8-0.9^{0}C for every increase in 100 m in the 400-1500 m elevation (Pascal 1982). In this elevation the mean temperature of the coldest months is 16-23^{0}C and that of the lower elevations is greater than 23^{0}C.

Land use and Biodiversity

The river basin has a total forest area of 1181.4 Km^2 (80%) and 256.2 Km^2 (20 %) of non forest lower plains. Of which primary forests dominates with 519 Km^2 (36%) followed by forest plantations 179.6 Km^2 (12%), secondary forests 197.4 Km^2 (17%), tea, coffee and other plantations constitute 198.3 Km^2 (13%), degraded non forest vegetation 86.9 Km^2 (6%) and reservoir, streams and rivers 46.5 Km^2 (3%) (Bachan 2010, Bachan and Pradeep 2010, Bachan et al. 2014). The vegetation map is given fig 3.3.

The area is extensively explored for its floristic diversity and vegetation. The major one's include Amitha Bachan (2010a, 2014, 2018a), Amitha Bachan et al (2008, 2014a), Amitha Bachan and Pradeep (2010, 2015), Amitha Bachan and Pooja (2017), Mini and Amitha Bachan (2007), Mohamed and Amitha Bachan (2006), Sini Thomas et. al. (2016), Thoiba and Amitha Bachan (2008), Sasidharan and Sivarajan (1997), Nasser and Amitha Bachan (2018),

Amitha Bachan (2010) has identified 319 species of flowering plants from the area, of which 24 are endemic species of the Western Ghats and 10 are in RET category.

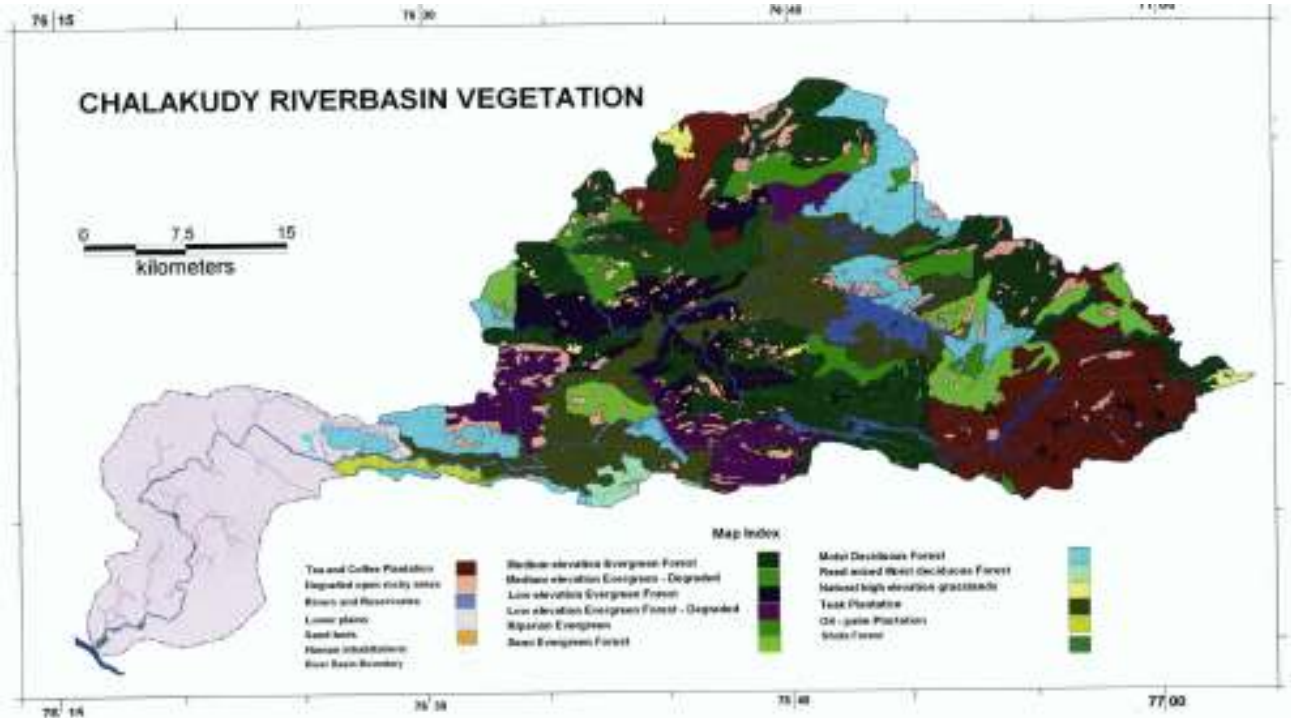

Fig. 3.3
Vegetation Map of Chalakudy Basin (Source: Amitha Bachan, 2010)

The riparian vegetation is estimated to have 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 (Amitha Bachan et al. 2014).

The faunal diversity in the area is also well explored. Major studies include Amitha Bachan (2009, 2010b&c, 2018b), Amitha Bachan et al (2009, 2011), Fasila et.al (2015), Nagesh Prabhu et. al (2005), Chyant and Amitha Bachan (2018a and b), Sidharth et.al. (2016) Amitha Bachan and Raseena (2016) Mohammed Safvan and Amitha Bachan (2018), Susanth (2012), Rison and Sherif (2017), Ajithkumar (1999), Akshay and Amitha Bachan (2018) . Sarkar *et al.,* **(**2008) has reported 71 species from Chalakudy River,

Socioeconomic profile

The Chalakudy river basin (CRB) covers 21 local bodies (BMCs) in Palakkad (2), Thrissur (14) and Ernakulam (5) districts. The main river passes through 14 local bodies. The distribution of the local bodies in various physiographic regions is given in Table 3.7.

Table 3.7
List of Local Bodies in CRB

Sl. No.	Local body	Sl. No.	Local body	Sl. No.	Local body
Palakkad Dist.					
1	Nelliyampathy (HHL/HL)*	2	Kizhakkanchery (HHL/HL)		
Thrissur Dist.					
3	Mattathur (HHL/HL)	8	Meloor (ML)*	13	Annamanada (ML)*
4	Kodasseri (HHL/HL/ML)	9	Chalakkudy Municipality (ML)*	14	Parakkadavu (ML)*
5	Athirappilly(HLL/HL)*	10	Alur (ML)	15	Poyya (ML)
6	Pariyarm (HL/ML)*	11	Mala (ML)*	16	Kuzhur (ML/LL)*
7	Koratty (ML)	12	Kadukutty (ML)*		
Ernakulam **District**					
17	Ayyampuzha (HL)*	19	Karukutti (HL/ML)*	21	Puthenvelikkara (ML/LL)*
18	Manjapra (HL)*	20	Mookkannur (ML)		

**Main river passing LBs HHL-High Highland, HL-Highland, ML- Midland, LL- Lowland*

The river is the life line of about 30 Local Self Governments (LSGs) and about ten lakh people.

Major Environmental Concerns

Major environmental issues threatening the biodiversity associated with the river system are: i) pollution from chemical factories as well as municipal wastes, ii) overexploitation of resources like sand and clay mining the lower reaches, iii) decreased natural flow in the summer months, iv) introduction of exotic species and v) other interventions like dams etc.

Many studies have shown that the water quality of Chalakudy river has been continuously changed (Chattopadhyay *et al*., 2005; Joseph and Tessy, 2010) and the ecology was threatened. An assessment of phytoplankton and physico-chemical characteristics of Chalakudy River was attempted by Leenamol and Tessy (2015). The investigation revealed that the water quality of Chalakudy River was highly deteriorated.

According to a study by Roshni e.al. (2016) the fishery resources in the river are highly threatened due to the introduction many exotic fishes in the reservoir. Other factors contributed to this include like habitat alteration, over-exploitation, pollution etc.

The dams and diversions have completely altered the natural hydrological regime in the river. The main river and major tributaries have been dammed at six places. The major dams in the Kerala part are Poringalkuthu LB HEP established by KSEB in 1957, Sholayar (PAP) – KSEB 1966, Chalakudy River Diversion Scheme (Department of Irrigation, 1959) and Idamalayar Augmentation Scheme (KSEB, 1990). In addition to the Tamil Nadu Government

owns 4 dams in this river (Thunakadavu, 1965; Parambikulam, 1967; Peruarippallam, 1971 and Sholayar. 1971) under Parambikulam Aliyar Project.

The natural summer flow in the river has reduced drastically due to various reasons including forest degradation and dams and diversions. The present river flow in non-monsoon months is almost entirely dependent on the storage at Kerala Sholayar and Poringalkuthu reservoirs. The downstream major irrigation project, the Chalakudy River Diversion Scheme (CRDS) does not have storage of its own. It is completely dependent on the tailrace discharge from the PLB – HEP. Over the last two decades, the daily flow fluctuation due to the semi-peaking operation of the PLB-HEP is affecting the functioning of CRDS. Recently works were initiated for construction of another dam at Athirappilly for hydropower generation (AHEP). One of the major issues projected with regards to AHEP was the downstream impacts of drastic intra-day flow fluctuation.

Conservation Initiatives

The recent campaigns against the proposed Athirappilly hydroelectric project (AHEP) and the pollution from Nitta Gelatin India Limited (NGIL) at Kathikudam had made the river to more public attention.

There are no major Government level interventions so far to protect the River system as whole from the existing threats described earlier. The River Research Center established in 2006, is the pioneer in initiating activities for protection of the River. The focused on grassroots education and policy advocacy to promote alternatives to benefit ecology and the poor.

Chalakudy Puzha Samrakshana Samiti (Chalakudy River Protection Forum) is the major NGO working in this direction for the past many years. They worked with groups like Asia Network on Dams and People (SANDRP) and the Forum for Policy Dialogue for Water Conflicts to map the various **uses** of the river including ecosystem use and thereafter devise an effective reservoir management strategy to resolve the dam controversy SANDRP has also initiated many studies support the movement against the Dam construction.

Community based conservation of river basins is another aspect which was greatly explored in this area. The major initiatives are documented by Amitha Bachan (2012), Amitha Bachan and Anitha (2013, 2017) and Amitha Bachan et al (2014b).

3.1.4 Bharathappuzha

Location and Geomorphology

Bharathappuzha, also known popularly known as *Nila*, is located at 10^0 26' and 11^0 13' north latitudes and 75^0 53' to77^0 13' east, is known as the cultural lifeline of Kerala (Fig. 2.13). The River could highly influence the History, Culture, Politics, Art, Literature, Knowledge of Kerala. The River has its origin from the Anamudi Peak -2695 mtr above MSL. The Basin area is 6186 Km^2 out of which 4400 Km^2 in Kerala, mostly Palakkad Dist. (Pl. 4) and 1786 Km^2 in Tamil Nadu – Coimbatore district. It is the second-longest River in Kerala, after the Periyar River with a total length is 209 Km of which about 46 Km in Tamil Nadu. For the first 46 km.

The main river is of 7^{th} order and among the four basins while river Chittur fall in 7^{th} order and all others fall in 6^{th} order.. The major tributaries of the river are: Kalpathippuzha, Chittar, Gayathrippuzha and Thoothappuzha. The Kalpathi basin is the largest sub basin with an area of 1390 sq.m., followed by Chittur (!315), Gayathri (1085) and Thootha (1015). Bharathappuzha follows an almost northerly course till Pollachi. At Parli both Kannadippuzha and Kalpathippuzha merge and flow as Bharathappuzha and follow a westerly course until it empties into the Arabian Sea at Ponnani. Thootha River merges with Nila at Pallippuram. As Thootha river, even though the smallest sub basin, is rich in water, and after its merger, Nila becomes thicker in flow. The river is not navigable along most of its course except the small stretch where it joins the sea. Though Bharathappuzha has a large basin, the water flow is relatively less compared to other long rivers in Kerala because a large portion of the basin is located in the comparatively drier regions (Tamil Nadu and Palakkad Gap).

The physiography and structural condition of the basin are the important factors influencing the number and order of the streams The location of the BRB in the Palakkad gap, the most prominent physiographic and morphologic feature, the 30 km wide opening in the whole of 1300 km long Western Ghats, provides a climatic realm for the basin from the rest of south India (Raj and Azeez, 2010). The average annual rainfall in the BRB is 1828 mm with a standard deviation of 456.6 mm. Among the months, while July experiences highest rainfall (525 mm), almost 29% of the total annual rainfall in the basin, January receives the lowest (3 mm). Among the two chief rainy seasons, rainfall is highest during south west monsoon season (1318 mm with a standard deviation of 391 mm) followed by north east The mean annual temperature of the basin was 22.86˚C with a standard deviation of 0.5˚C. April is the

hottest (mean temperature 26.78˚C) month in the basin. The annual discharge of the river at its confluence is 3.94 km^3 (Raj and Azeez, 2009)

Land use and Biodiversity

One of the major studies to assess the land use and its changes of Bharathappuzha basin is by Nikhil Raj and Azeez (2010). The spatial and temporal changes in land use and land cover (LULC) were conducted using Remote Sensing and GIS. The study used multispectral LANDSAT imageries of 1973-2005 time periods. During the early period (1973-1990) of the study, land under natural vegetation cover (44%) dominated followed by the area under agriculture. During the second half of the study period land under urban centers became important (32%) followed by the area under plantation. The area under agriculture remained almost same (26%), while the area under natural vegetation cover declined to considerably lower proportion in the total area of the basin. In 2005, the area under urban centers remains as the major land use type in the basin, followed by agriculture at the second position. In over all, the area under the natural vegetation cover consistently showed a trend of drastic decline. On the other hand growth in urban centers in the basin was observed during the whole period. About 31% depletion in the natural vegetation cover and 8.7% depletion in wetland agriculture area were seen in the basin during the period. On the other hand the urban spread in the basin increased by 32%. The study highlights the need for a scientific management plan for the sustainability of the river basin, keeping in view the recent climatic anomalies and hydrological conditions of the basin.

There are many scattered studies to explore the riparian flora of the river. Cherullipadi and Paul (2016) studied the diversity of herbaceous riparian flora in the lower stretch of Bharathappuzha, Kerala. In this study the herbaceous flora of the riparian forest of lower stretch of Bharathappuzha was analyzed taxonomically and phyto-sociologically. There are 176 angiosperms belongs to 63 families, 4 pteridophytes in 2 families and 1 gymnosperm in Cycadaceae. The herbaceous flora composed of 73 species in 29 families. Jisha, *et al*., (2017) conducted a study on the Angiosperm diversity of Kanjirapuzha, one of the major tributary of Thootha River and analyzed the angiosperm diversity along the riparian system of Kanjirapuzha along with phytogeographical affinities. Documentation of riparian vegetation along Kanjirapuzha basin recorded 196 species of flowering plants under 62 families. In this study it was also found that there is a gradual reduction in the number of native and strict riparian elements and a massive inhabitation of invasive elements. Jisha and Nair (2018) analyzed the diversity of angiosperms in the riparian system of Thuppanadupuzha, one of the

tributary of Thoothappuzha and summarize the angiosperm diversity along the riparian system of Thuppanadupuzha along with its phytogeographical affinities, percentage endemism, morphological adaptations and biological invasion. The analysis on endemism revealed that thirty four taxa are endemic to Western Ghats and at the same time, broad scale phytogeographical affinities of the riverine flora extend to African, Australian, Holarctic, Indo-Pacific and South American floristic kingdoms. The altitudinal profiling of the vegetation along the riverine belts revealed higher degree of variation in floristic elements and in the low land belts, human intervention and pollution has resulted in the gradual shift of vegetation elements into alien and invasive ones.

Faunal studies are mostly restricted to fishes. Biju et al. (2000) studied the exotic fishes and fresh water fish diversity of Kerala and reported 67 fish species from Bharathappuzha and its tributaries. Bijukumar and Sushama (2001) analysed the fish fauna of Bharathappuzha River and recorded 61 species from Bharathappuzha river system with a focus on the threats to faunal diversity and conservation measures. Radhakrishnan et al (2006) studied the Mangroves and their faunal associates in Kerala. In Bharathappuzha they found that there are 5 important mangrove species, 22 species of shorebirds, and 12 species of sea birds could be recorded from these areas. Large aggregation of sea gulls, especially species like Brown headed Gull (*Larus brunnicephalus*), Black headed Gull (*L. ridibundus*), Pallas Gull (*L. ichthyaetus*), Heuglin's Gu)) (*L. argentatus*), etc., were sighted near Purathur area. Rare birds like Greater Flamingo (Phoenicopterus roseus), Oystercatcher (*Haematopus ostralegus*), Crab Plover (Dromas ardeola), and Masked Booby (*Sula dactylatra*) were also recorded from the locality. Nesting of Black billed tern (*Sterna acuticauda*), a globally threatened bird species was also recorded from the sand banks of Bharathappuzha. Large numbers of white necked Storks (Ciconia episcopus) and Open bill Storks (*Anastomus osciana*) were regularly sighted from the further upstream areas close to the estuary. The breeding of small Pratincole (Glareola lacteal) and Little Ringed Plover (*Charadrius dubius*) has also been reported from the banks of Bharathappuzha. An assemblage of about two dozens of Reef Heron (Egretta gularis) was noted near the estuary. They also noted that this mangrove associated wetlands and estuarine habitats are amply abused by the indiscrete and ruthless practice of poaching of these water birds. Kumar et al., (2013) analysed the comprehensive account of the diversity, distribution, threats, and suggest conservation measures for the fishes of Bharathappuzha and recorded that a total of 117 fish species under 43 families belongs to 81 genera. It was also found that Several anthropogenic stressors including deforestation and loss of riparian cover, dams and other impoundments, pollution, sand mining, non-native species and destructive

fishing practices are threatening the rich ichthyofaunal diversity and endemism in the Bharathappuzha. Divya and Manonmani (2014) studied the Impact of domestic sewage pollution on zooplankton diversity in Bharathappuzha river and summarizes that four major groups were identified namely protozoa, roifera, cladocera and copepod and the highest species diversity was recorded in the month of June especially in pre monsoon period. It was also found that temporary stagnant untreated domestic sewage leads to eutrophication and these conditions can be favourable for rotifer because of their short life-cycle, food and feeding habitats, metabolisms and pathenogenetic mode of reproduction which increase their density. Renjithkumar et al., (2016) analysed the Composition of non-native fishes in the exploited fishery of Bharathappuzha and found that an urgent monitoring of the population stocks of non-native fishes and the formulation of a proper regulation strategy is of immediate need to conserve the diverse native fish fauna of the river.

Socioeconomic profile

The Bharathappuzha river basin (BRB) covers 119 local bodies (BMCs) in the state of Kerala (113 Grama Panchayats and 6 Municipalities) of which 91 are in the Palakkad district, 10 in Thrissur and 18 in Malappuram district. The main river passes through 37 local bodies (33 Grama Panchayats and 4 Municipalities); 22 in the Palakkad district, 8 in Thrissur and 7 in Malappuram district. The distribution of the local bodies in various physiographic regions is given in Table 3.8.

Table 3.8
List of Local Bodies in CRB

Sl. No.	Local body	Sl. No.	Local body	Sl. No.	Local body
Palakkad Dist.					
1	Erthampathy (HL)*	32	Melarkkode (HL/ML)	63	Mannarkkad (HHL/HL/ML)
2	Kozhinjampara (HL)*	33	Nemmara (H/MLL)	64	Pudur (HHL)
3	Vadakarapathy (HL)*	34	Elevacherry (HL)	65	Kumaramputhur (HHL/HL/ML)
4	Puthussery (HL)	35	Kollengode (HL)	66	Kottoppadam (HHL/HL)
5	Elappally(HL)*	36	Vadavannur (HL)	67	Thachanattukara(HL/ML)
6	Marutha Road (HL)	37	Pallassana(HL)	68	Cherplassery (ML)
7	Palakkad MPTY (HL)*	38	Erimayur (HL)	69	Nellaya (ML)
8	Malampuzha (HHL/HL)	39	Alathur (HL/ML)	70	Kulukkallur (ML)
9	Akathethara (HL)	40	Kavassery(HL/ML)	71	Koppam (ML)
10	Puthuppariyaram (HL)	41	Tharur (HL/ML)	72	Vilayur (ML)
11	Parali (HL/ML)*	42	Perungottukurissi (ML)*	73	Thirvegappura (ML)

Sl. No.	Local body	Sl. No.	Local body	Sl. No.	Local body
12	Mankara (HL/ML)*	43	Kuthannur (HL/ML)	74	Paruthur (ML)*
13	Keralasseri (HL)	44	Kuzhalmannam (HL)	75	Aanakkara (ML)*
14	Kongad (HL)	45	Thenkurissi(HL)	76	Pattithara (ML)*
15	Mundur (ML)	46	Koduvayur (HL)	77	Kappur (ML)
16	Karimba (HL/ML)	47	Puthunagaram (HL)	78	Thrithala (ML)*
17	Kadambazhippuram (ML)	48	Chittoor-Thathamangalam MPTY (HL)	79	Muthuthala (ML)*
18	Karakkurissi (ML)	49	Peruvembu (HL)	80	Pattambi (ML)*
19	Kottayi (ML)*	50	Mathur (HL/ML)	81	Nagalassery (ML)
20	Pirayiri (HL)*	51	Mannur (HL/ML)	82	Thirumittakkode (ML)*
21	Kannadi (HL)	52	Ottappalam MPTY (ML)*	83	Puthucode (ML)
22	Kodumbu (HL)	53	Lakkidi-Peroor (ML)*	84	Kannampra (HL/ML)
23	Polppully (HL)	54	Ambalappara (ML)	85	Kizhakkancherry (HL/ML)
24	Nallepilly (HL)	55	Thrikkadeeri (ML)	86	Vaniyamkulam (ML)*
25	Perumatty (HL)	56	Pookkottukave (ML)	87	Ongallur (ML)*
26	Pattencherry (HL)	57	Sreekrishnapuram (ML)	88	Shornur MPTY (ML)*
27	Muthalamada (HL)	58	Vellinezhi (ML)	89	Chalavara (ML)
28	Nelliyampathy (HHL/HL/ML)	59	Karimpuzha (ML)	90	Anaganadi (ML)
29	Vandazhi (ML)	60	Kanjirappuzha (HL/ML)	91	Vallapuzha (ML)
30	Ayiloor (ML)	61	Thachampara (HL/ML)		
31	Vadakkancherry (HL/ML)	62	Agali (HHL/HL/ML)		
Thrissur Dist.					
92	Thiruvilwamala (ML)*	96	Erumapetty (ML)	100	Kondazhy (HL/ML)*
93	Desamangalam (ML)*	97	Mulloorkara (ML)*	101	Pazhayannoor (HL/ML)
94	Varavoor (ML)	98	Panjal (ML)*		
95	Vallathol Nagar (ML)*	99	Chelakkara (HL/ML)*		
Malappuram District					
102	Aaliparambu (ML)	108	Edayoor (ML)	114	Tavanur (HL/LL)*
103	Thazhekkode(ML)	109	Marakkara (ML)	115	Thirunavaya (ML) *
104	Perinthalmanna MPTY (ML)	110	Athavanad (ML)	116	Triprangode (LL)*
105	Elamkulam (ML)	111	Valancherry (ML)	117	Vattamkulam (ML)
106	Pulamanthole (ML)	112	Irimpiliyam (ML)*	118	Purathur (LL)*
107	Moorkkanad (ML)	113	Kuttippuram (ML)*	119	Ponnani MPTY (LL)*

**Main river crossing LBs, HHL-High Highland, HL-Highland, ML- Midland, LL- Lowland*

The river is the life line water resource for more than 4.5 million people residing in five administrative districts, namely Malappuram, Thrissur and Palakkad districts of Kerala, and

Coimbatore and Thiruppur districts of Tamil Nadu. There are eleven dams and irrigation projects in the river basin catering 493,064 ha cultivations (CWRDM, 2004).

In addition to its geo-physical value, the river very much significant for its cultural and historical significance. The river valley is considered the cradle of civilization in Kerala and the influence of Nila on the cultural formation of the people of Kerala is invaluable. The river which was an inspiration for writers, dancers and musicians etc. Very eminent personalities in the Indian political and administrative services were born and brought up in the banks of the river.

Major Environmental Concerns

The BRB is one of the highly exploited river basins in the state of Kerala. In the recent years, the river is facing severe dearth of water and drought like situations. This is mainly because of increasing anthropogenic pressures and unsustainable development activities neglecting the hydrologic flow regime of the basin. Unsustainable exploitation of water, in stream sand mining and clay mining for brick kilns are among the striking threats to flow of the river. The major environmental threats to river are due to:

Dams: The eight dams built across the various tributaries have often adversely affect the flow pattern, extent and nature of sediment formation and deposition, riverine biodiversity and the quality of water. It has been found that there is reduction in river flow after the construction of the dams in various tributaries of Bharathappuzha. No flow in the downstream of these dams resulted to the drying up of the lower reaches of these tributaries especially during the summer months. The reduction in flow in the downstream reaches will increase the intrusion length of salinity from estuary and deteriorate the quality status of the river water.

Deforestation: Massive deforestation of the rich climax evergreen, deforestation of midland hillock forests for cultivation, submergence and cutting down of forests for dams and State induced deforestation for raising forest plantations. Heavy deforestation have left their trail of impact affecting the river flow, river ecology, water table and water quality across the length and breadth of the river.

Over exploitation of ground water: High water demanding crops like sugarcane and paddy are being cultivated in the area using the bore well water. Unscientific groundwater development for industrial and agriculture purposes in certain blocks lead to high stage of groundwater development (critical and over exploitation). The stage of ground water development with regard to the entire basin is 50.62 percent.

Climate change: The analysis of the trend of temperature in the basin shows an overall upward trend in mean annual and daily temperature. The temperature during winter and the southwest and northeast monsoon periods also showed significant increase. The increase in the annual mean temperature in the basin presumably would have an impact on rainfall and local climate. It was found that the annual rainfall in the basin shows a decreasing trend. The climate change also shows a negative impact on water resources and land use of the basin.

Sand mining: Amongst the causes for the degradation of the river, sand mining is the gravest and dominant one. It is one of the rivers in Kerala heavily utilised for sand mining. Illegal sand mining in the river is quite regular and usual devoid of protective laws against mining, intervention of authorities and courts. The impacts of unsystematic sand mining on environment and other physical conditions are indisputably severe. Though the general impacts are same, specific negative impacts are diverse. Demand for sand from this river

Clay Mining: The brick building industries in the banks of the river as well from outside areas has exploited huge quantities of alluvial soil from the river banks

An expert committee appointed by the Government of Kerala to investigate into the problems of Bharathappuzha (1997) reports, "the Bharathappuzha system is seriously affected by unsustainable exploitation of its resources and over utilisation of its surface and ground water resources, particularly in the lean period. The indiscriminate sand removal has almost killed the river (The Hindu, 2003). The uncontrolled sand-mining has damaged the river's ecosystem as well, destroying the habitat of organisms living on the river bed. Fish breeding and migration have been affected because of the sand-mining (The Hindu, 2012). Dinesan (2012) observed that the river shrank into rivulets and these are meandering through some portions of the river bed. As the river bed is dry for most of the period, the farmers grow vegetables on the bed. Research studies have been reporting about the pathetic condition of the river which in turn causes damages to the ecosystem in and around the river, agricultural activities dependent on the river, physical structures over the river and the river based tradition and culture built around the state. In short, the present state of the river has become a matter of serious concern to the people, authorities, scientist, environmentalist and other stake holders.

Conservation Initiatives

There are many initiatives for conservation of the River from many Government programs like the Rural Development Department program but none of them had an integrated approach and is failed.

Many Non Government Organization has also initiated many programs. Nila foundation was one such organization worked earlier in this direction. Similarly t NGO's such as Nilavu, Vayali Folklore Group and The Bharathappuzha Protection Committee has also worked for the conservation of the different cultures on the river banks through travelling on the banks, documentation of community life and making awareness among the public through different media. However, there is a need proper scientific documentation of the current status of the river and developing an action plan with integrated approach and its implementation through all stakeholder participation.

3.2 RIPARIAN AREAS SURVEYED DURING THE STUDY

Pampayar: 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).

Periyar: 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. In addition to this, the diverted River stretch from Aluva to Varappuzha Bridge (16 km), Muthirappuzhayar tributary from Kallarkutty Dam to Panamkutty (4km), Pooyamkuttyar tributary from Kandapapara to Anakulam (8.2) and the Idamalayar tributary from Idamalayar Dam to Bhoothathankettu (18km) are also explored. The total length of the riparian area studied is thus 208 km (Plate 6) and was explored on the both banks.

Chlakkudiyar: 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 (Plate 7).

Bharathappuzha: In Bharathappuzha, the study is concentrated to the three major tributaries viz. Kalpathippuzha, Gayathrippuzha and Thoothappuzha (Plate 8). In Kalpathippuzha the river stretch from Kanjikode West to Parali, around 26 km was explored; in Gayathrippuzha the area explored is from Mangalam Bridge to Ottapalam, around 30 km and in Thoothappuzha, Thathengalam to Pallippuram stretch, about 80 km explored. The total length of the river studied in Bharathappuzha is136 km.

3.3 APPROACH AND METHODOLOGY

3.3.1 Involvement Scientist Explored the Area Earlier

The study was proposed to make use of the service of the scientist who has explored the riparian areas of the rivers for its riparian floristic diversity and its ecological significance in recent years for conducting the impact assessment of the area. The major studies and Taxonomists who has directly involved in undertaking floristic studies in recent years are:

i. Studies on the Riparian Flora and Phytogeography of Pampa River (Dr. Joby Paul et.al., St. Thomas College, Thrissur)
ii. Floristic studies in Ernakulam District - (Dr. Sunil C N et. al, Prof. & Head, Research & Postgraduate Dept. of Botany (Rted.), SNM College, Mallyamakara)
iii. Studies on the Riparian flora of the highland areas of Periyar - (Dr. Jomy Augustine et. al, Prof. & Head, Research & Postgraduate Dept. of Botany, St. Thomas College Pala)
iv. Enumeration of Riparian vegetation in the midland and highland areas of Periyar (Dr. Sabu T , CED, Thiruvananthapuram)
v. Study on the Riparian flora of Chalakudy River - Survey, mapping, community studies and identification of the residual pockets for conservation(Dr. Amitha Bachan K.H., MES Asmabi College, Kodungallur)
vi. Studies on the Riparian Flora of major tributaries of Bharathappuzha (Thoothappuzha and Kanjirapuzha) (Maya C Nayar et. al. Govt. Victoria College, Palakkad)

Involvement of these scientists in the study has provided clear idea on the changes occurred with respect to the vegetation.

3.3.2 Participatory Approach for Data collection involving BMC Members

In order to assess the previous condition of the study area and local knowledge on the utilization of the flora, the study followed a participatory approach by involving BMCs representatives and local people.


VSS Participation Paniveli


Forest Staff at Pampa


Students Participation in Periyar


Stakeholder Consultation in Bh[illegible]uzha

The officials and staff from Kerala Forest Department also consulted and involved in the study in the forest areas explored. Post graduate students from St. Thomas College were participated in the studies in Idukki district.

3.4 MAJOR ACTIVITIES

The flow chart on the activities involved in the study is given in Fig.3.4. The major activities are further detailed here.

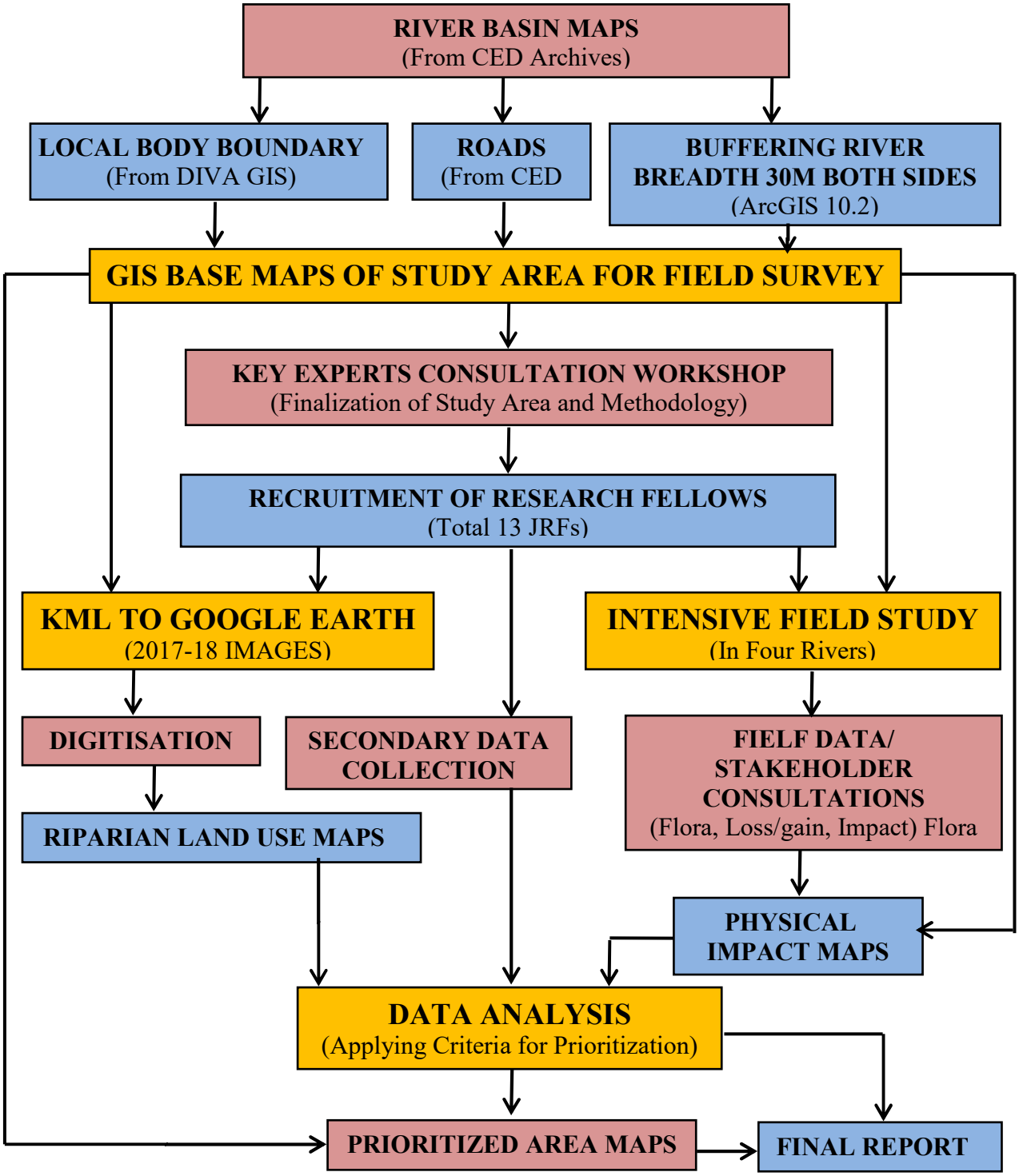

Fig.3.4
Flow Chart of the Activities

3.4.1 Preparation of base maps field study

The base maps of the study area showing major roads and important places are prepared at a higher scale with grid lines at 10 seconds interval. The river basin maps available with CED archives are used for this purpose. The river breadth in the selected study area of all the four rivers were buffered 30 m on both sides as the riparian zone. Sample map is given in Fig. 3.5

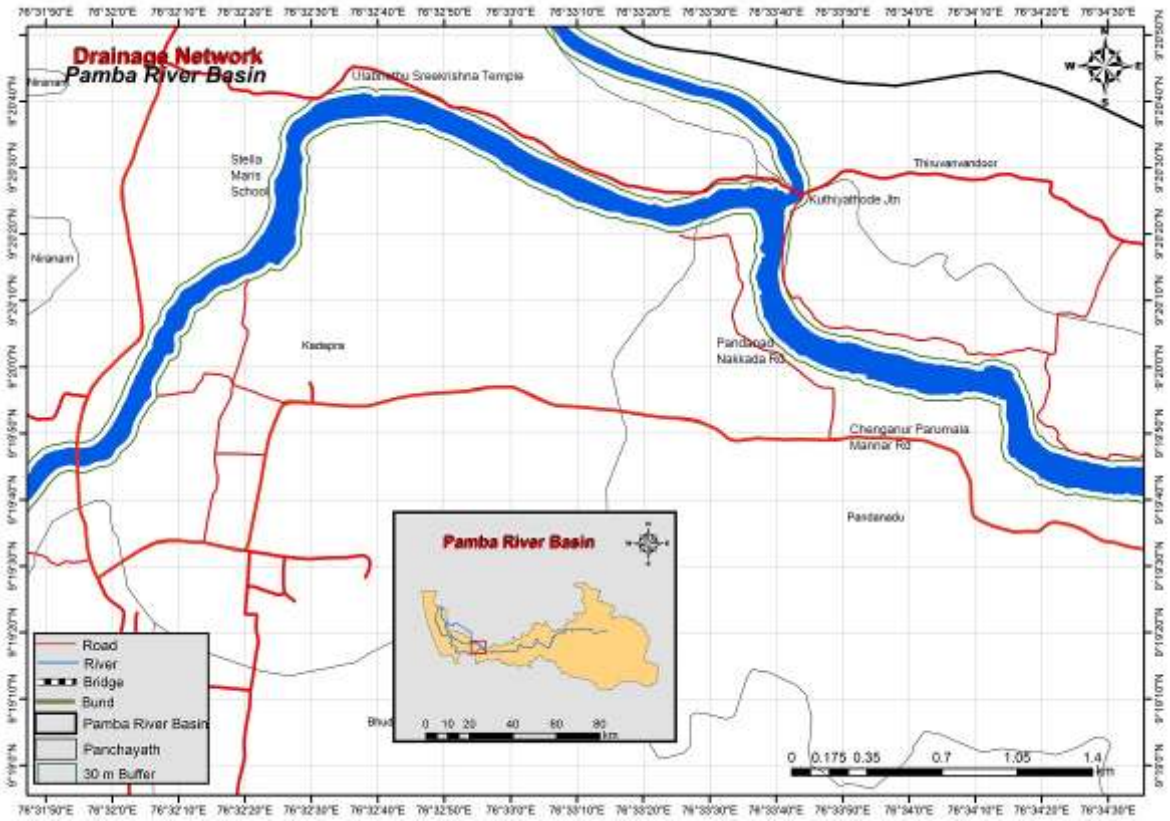

Fig. 3.4
Sample map used for Field Study

3.4.2 Key Experts Consultation Workshop

On initiation of the project, the key experts conducted rapid assessment of the corresponding river through filed visits. After the visit, a consultation workshop with key experts was conducted at St. Thomas College Thrissur for refining methodology proposed for the study. All the five key experts and the PI attended the meeting.


Meeting of Key Experts at Thrissur

The consultation workshop discussed and finalised the plan of work and data sheet for field data collection. Based on the preliminary survey conducted it is also decided make some additions to the proposed study location by adding some more areas where heavy damages are taken place. The details of study area finalised for detailed study is discussed below.

3.4.3 Recruitment of Research Fellows for Data Collection and Analysis

The following research fellows were recruited for assisting the PI and Key experts for data collection from the field and analysing the data:

1. Shaibu Jacob – Pampayar
2. Vishnu T J – Pampayar
3. Tom Mathew – Periyar (Idukki District)
4. Krishnanand– Periyar (Idukki District)
5. Akshath Shenoy– Periyar (Ernakulam District)
6. Nitheesh T N– Periyar (Ernakulam District)
7. Pooja Suresh - Chalakudyar
8. Sreehari – Chalakudyar
9. Akhila S – Bharathapuzha
10. Laiju CK – Bharathapuzha
11. Arun C Rajan – Assist field work in Pampa and compilation of report at CED
12. Akhil S. Son – GIS Mapping
13. Prasood S – GIS Mapping

3.4.4 Literature Survey and preparation of an appraisal of the study area

Through a detailed literature survey, the study has prepared a detailed appraisal of the study area. The studies with respect to different aspects were compiled and discussed.

3.4.5 Getting permission from Authorities to enter Restricted Areas

Part of the study area is coming under various Forest Divisions in Kerala. In order to enter the forest area for data collection we need permission from the Department of Forest and wildlife, Govt. of Kerala. Accordingly permission was received wide letter no. KFDHQ-30185/2018-CWW/WL10 dated 8th January, 2019 to enter the following forest areas:

i. Bharathappuzha – Mannarkkad, Palakkad and Nenmara Forest Divisions
ii. Chalakudyar - Vazhachal and Chalakudy Forest Divisions
iii. Periyar – Munnar and Malayattur Forest Divisions and Idukki Wildlife Sanctuary
iv. Pampa - Kottayam and Ranni Forest Divisions and Periyar Tiger Reserve

The permission letter is given as annexure 1.

3.4.6 Intensive field surveys along the river banks

Field surveys were undertaken by the research fellows using the grid maps with the guidance and participation of key experts who has studied the region earlier. The major aspects noticed along river banks of the study area are:

i. Place name of the area marked in the map

ii. Physical feature of the area (Cliff/Steep slope/Medium slope/Gentle slope)
iii. Details of Bank erosion/slumping during flood (High – top to bottom eroded, Medium - around half portion from the top eroded and low- top soil from the bank eroded)
iv. Details of mud/sand deposition during flood (High -complete covering with more than 1m height, Medium-moderate covering with less than 1m height and low- scattered deposition)
v. Flood Water Level at top point of bank (m)
vi. Major Vegetation Type on the banks before flood (Natural Vegetation of wild plants/ Plantation/Mixed tree species/ paddy/Vegetable cultivation etc.
vii. Current vegetation type with names of species
viii. Changes in vegetation type/species composition due to flood/landslide
ix. Presents and distribution of invasive species
x. Community perception on the species lost, if any (local importance of species – used as medicine, food, religious purpose, raw material for local livelihood activities, breeding, nesting and feeding habitats of wild animals helped protection of banks etc)

The impact of flood/landslide was also photo documented during the field study.

3.4.7 Analysis of collected data

The data collected were critically analysed to identify the loss species with respect to its conservation importance like IUCN threatened status, endemism, breeding and nesting areas of animals, river bank protection etc. The new addition of invasive species in certain locations were also analysed critically.

Based on the data analysis, the study has developed certain criteria for prioritization of the areas for intervention and different levels. This was done in consultation with experts and the criteria developed are discussed in the result part.

3.4.8 Preparation of GIS maps

Riparian Land Use Maps Before Flood/Landslide

The KML files of the base maps prepared is opened in the Google Earth and the broad land use classes like natural vegetation of wild plants, plantation (Coconut, Rubber, Oil Palm, Tea etc.), Mixed cultivated tree species, Paddy, Mixed vegetable cultivation etc.. for the pre flood/land slide period (2017-18, based on clarity of image) were digitise. The initial maps prepared were taken to the field for checking correctness and corrections were made accordingly before finalization of maps.

Physical Impact Maps

The data collected on the physical impact to the riparian areas (Erosion and Deposition) were incorporated in to the base map in GIS environment and the impact maps were prepared. These maps then added to the land use map as different layer and the combined maps showing vegetation types and areas of erosion/deposition were prepared.

Maps showing prioritised areas for intervention

The areas prioritised for intervention through the data analysis were incorporated in the maps in GIS platform and the maps showing prioritised areas for intervention were prepared.

After analysis of the data the area requiring future intervention were prioritized based on various criteria like physical impact, vegetation pattern, presence of conservation important species, and distribution of in invasive weeds.

3.4.9 Preparation of detailed report

Based on the study and analysis of data, this detailed report of study with maps, photographs etc. was prepared.

CHAPTER 4
RESULTS OF THE STUDY

4.1 ASSESSMENT OF RIPARIAN FLORA

4.1.1 Enumeration of Floristic Diversity

The study has identified a total number of 1243 species of phanerogams belonging to 150 families from the four rivers under study (Annexure II). This includes 945 Dicotyledons, 296 Monocotyledons and 2 Gymnosperms.

The largest family is Poaceae with 114 species followed by Fabaceae (113), Cyperaceae (64), Rubiaceae (64), Euphorbiaceae (63) and Asteraceae (56). Other large families with 15 or more species are: Acanthaceae (31), Moraceae (30), Scrophulariaceae (30), Convolvulaceae (27), Malvaceae (20), Lamiaceae (19), Verbanaceae (18), Amaranthaceae (17), Apocynaceae (17), Commelinaceae (17), Zingiberacae (17), Annonaceae (16), Myrtaceae (16), Orchidaceae (16), Melastomataceae, (15) and Solanaceae (15). There are 53 families with only one species recorded from the area.

Majority of the riparian flora recorded from these four Rivers are herbs (582), followed by trees (307), shrubs (192) and climbers (162). The habit wise distribution pattern of the floristic elements is given in fig. 4.1

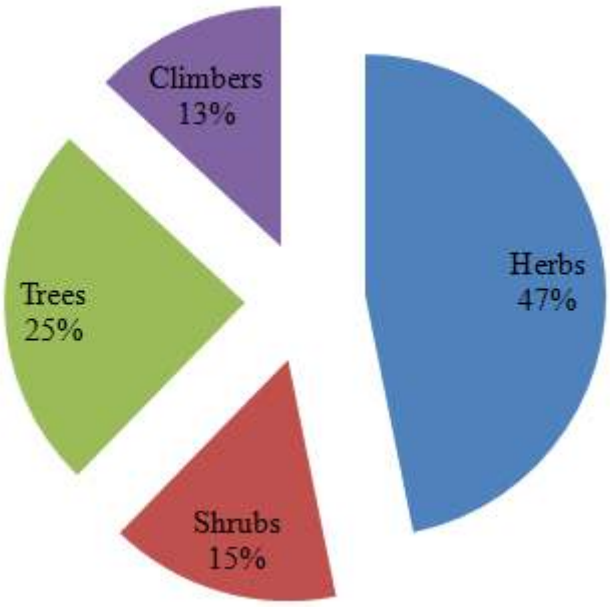

Fig. 4.1
Habit wise Distribution Pattern of Species in the Four Rivers

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, Vitex leucoxylon 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, Pandanus canaranus, Pandanus kaida, Pandanus odorife, Pandanus palakkadensis, Phyllanthus lawii, Rhizophora mucronata, Syzygium caryophyllatum, Ochlandra scriptoria and Ochlandra travancorica.* This includes 4 Mangroves.

It is noted that 80 out of the 162 climbers identified are stragglers/woody climbers and remaining 82 are slender climbers. 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 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. The flora also consists of 197 exotic species of which 48 species are included in the 82 invasive species of Kerala identified by Sankaran et.al. (2013). 60 species out of the 91 cultivated plants are exotic species and it also include 4 invasive species listed by Sankaran et.al. (2013). The distribution pattern is shown in Fig. 4.2.

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 rive 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.

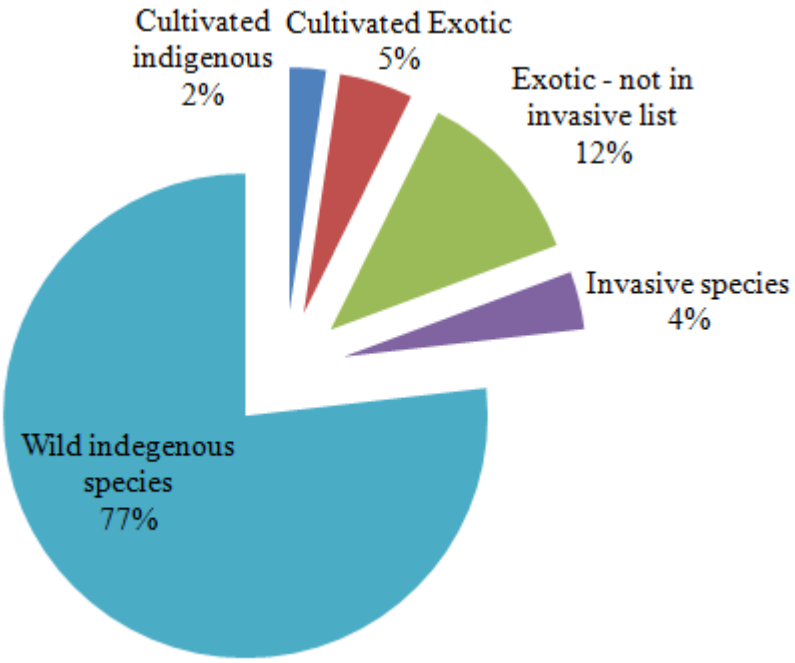

Fig. 4.2
Distribution Pattern of Floristic Elements in the Four Rivers

4.1.1.1 Riparian Flora of Pampayar

The total number of plants recorded is from Pampa River of 549 belonging to 112 families. This includes (392 Dicotyledons, 156 Monocotyledons and 1Gymnosperms).

The largest family is Poaceae with 52 species followed by Fabaceae (48), Euphorbiaceae (33), Rubiaceae (29), Cyperaceae (23), and Asteraceae (20). Other large families with 10 or more species are: Moraceae (16), Verbanaceae (12), Acanthaceae (11), Commelinaceae (11), and Convolvulaceae (11). There are 40 families with only one species recorded from the area.

Out of 549 species of riparian flora identified from the riparian region of Pampayar, majority are herbs (221), followed by trees (172), shrubs (85) and climbers (71). The distribution pattern of the floristic elements is given in fig. 4.3.

In the herbaceous group, there are 111 annuals and remaining 110 are perennials. 31 herbaceous species are restricted to the water body area or wet places nearby like marshes. There are 8, epiphytes and 1 parasite in the herbaceous group

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.

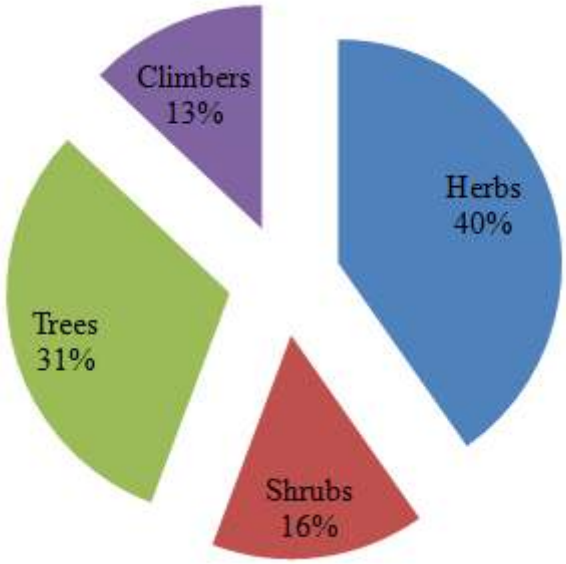

Fig. 4.3
Habit Wise Distribution Pattern of Flora in the Riparian Region of Pampayar

They are also 8 shrubs growing along the immediate banks. They are: *Ficus heterophylla, Homonoia riparia, Pandanus canaranus, Pandanus kaida, Pandanus odorifer, Phyllanthus lawii, Ochlandra scriptoria and Ochlandra travancorica.*

In the climbing plants group 35 species are stragglers/woody climbers and remaining 36 are slender climbers. Three woody climbing plants viz., *Combretum albidum, Derris trifoliate and Entada rheedei* are seen growing very close to the water flowing areas.

The distribution pattern of the species with respect to its exotic/indigenous status is shown in Fig. 4.4.

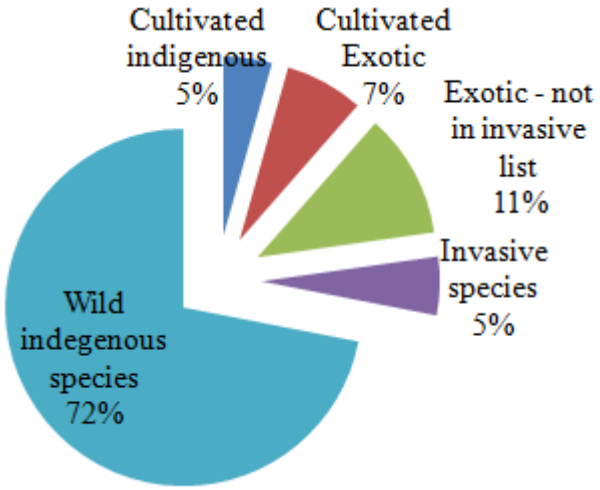

Fig. 4.4
Distribution Pattern of Floristic Elements in Pampayar

Out of the 549 species recorded from the study area of Pampayar, 63 species (10 herbs, 9 shrubs, 37 trees and 7 climbers) are cultivated species grown by the farmers along the banks of the river. The flora also consists of 91 exotic species of which 29 species are included in the 82 invasive species of Kerala identified by Sankaran et.al. (2013). 39 species out of the 63 cultivated plants are exotic species and it also include 4 invasive species listed by Sankaran et.al. (2013).

4.1.1.2 Riparian Flora of Periyar

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. This includes (621 Dicotyledons, 176 Monocotyledons and 2 Gymnosperms).

The largest family is Fabaceae with 87 species followed by Poaceae (84), Cyperaceae (43), Euphorbiaceae (42), Asteraceae (41) and Rubiaceae. Other large families with 10 or more species are: Scrophulariaceae (24), Moraceae (22), Convolvulaceae (20), Acanthaceae (16), Verbanaceae (15), Lamiaceae (14), Apocynaceae (13), Malvaceae (12), Amaranthaceae (11) and Solanaceae (11). There are 41 families with only one species recorded from the area.

The riparian flora identified from the riparian region of Periyar consists of 372 herbaceous species, 204 trees, 114 shrubs and 109 climbers (71). The distribution pattern of the floristic elements is given in fig. 4.5.

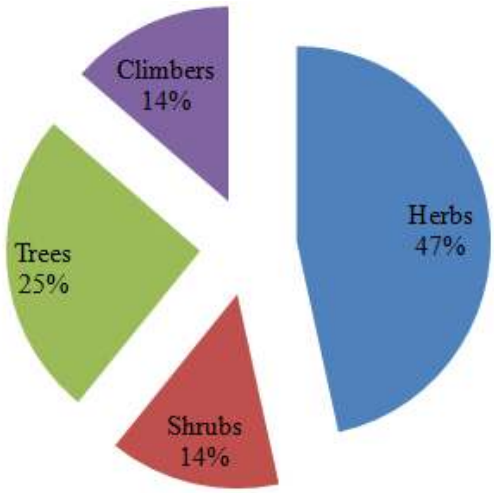

Fig. 4.5
Habit Wise Distribution Pattern of Flora in the Riparian Region of Periyar

Out of the 372 herbaceous species identified, 221 are annuals and remaining 151 are perennials. 45 herbaceous species aquatic or semi aquatic with distribution restricted to the running/stagnant water or water logged/wet areas like marshes, paddy fields etc. There are 2 epiphytes, 1 saprophytic herbs of the family Orchidaceae.

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.*

Out of the 162 climbing plants identified, 80 are stragglers/woody climbers and 82 are slender climbers. Three woody climbing plants viz., *Combretum albidum, Derris trifoliate and Entada rheedei* are growing close to the River.

Out of the 799 species recorded from the study area of Periyar, 61 species (10 herbs, 7 shrubs, 40 trees and 4 climbers) are cultivated species grown by the farmers along the banks of the river. The flora also consists of 136 exotic species of which 34 species are included in the 82 invasive species of Kerala identified by Sankaran et.al. (2013). 40 species out of the 61 cultivated plants are exotic species and it also include 4 invasive species listed by Sankaran et.al. (2013). The distribution pattern of the species with respect to its exotic/indigenous status is shown in Fig. 4.6.

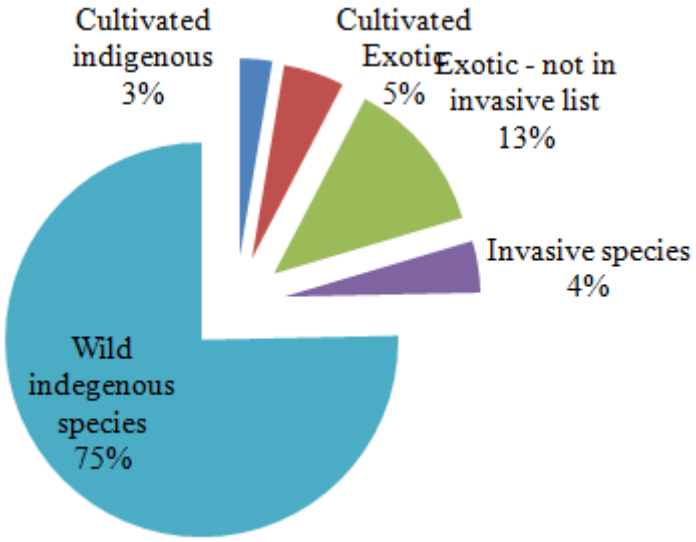

Fig. 4.6
Distribution Pattern of Floristic Elements in Periyar

4.1.1.3 Riparian Flora of Chalakudyar

The present study enlisted 470 species belonging to 108 families from the riparian zone of Chalakudy River. This includes (363 Dicotyledons, 107 Monocotyledons).

The largest family is Fabaceae with 40 species followed by Poaceae (36), Euphorbiaceae (25 and Cyperaceae (20). Other large families with 10 or more species are: Moraceae (17), Asteraceae (16), Rubiaceae (16), Acanthaceae (11), Annonaceae (10), Clusiaceae (10), Convolvulaceae (10) and Orchidaceae (10). There are 46 families with only one species recorded from the area.

The riparian flora identified from the riparian region of Periyar consists of 178 herbaceous species, 168 trees, 68 shrubs and 56 climbers (71). The distribution pattern of the floristic elements is given in fig. 4.7.

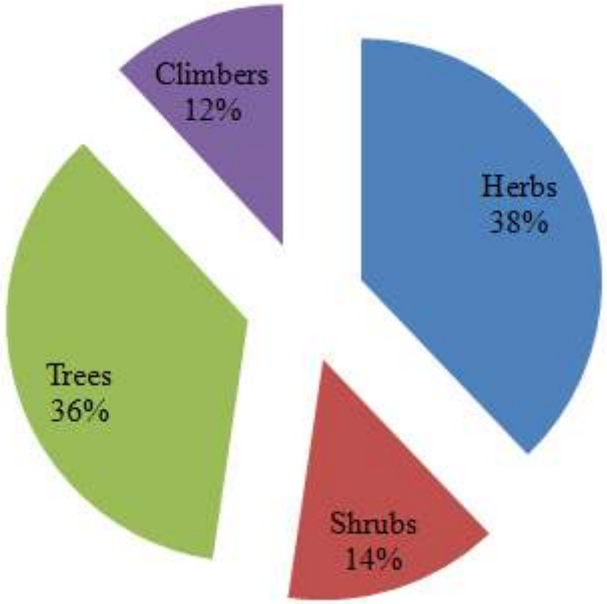

Fig. 4.7
Habit Wise Distribution Pattern of Flora in the Riparian Region of Chalakudyar

Out of the 178 herbaceous species identified, 96 are annuals and remaining 82 are perennials. 23 herbaceous species aquatic or semi aquatic with distribution restricted to the running/stagnant water or water logged/wet areas like marshes, paddy fields etc. There are 10 epiphytes, 2 saprophytic herbs and 1 parasite.

Out of the 168 tree species identified 21 are mostly seen close to the immediate banks of the River. They are: *Barringtonia acutangula, Calophyllum calaba, Cinnamomum riparium, Crateva magna, Ficus hispida, Garcinia Morella, Hopea parviflora, Hopea ponga, Humboldtia vahliana, Lagerstroemia microcarpa, Lophopetalum wightianum, Madhuca neriifolia, Mallotus atrovirens, Neolamarckia cadamba, Ochreinauclea missionis, Syzygium*

laetum, Syzygium occidentalis, Terminalia elliptica, Thespesia populnea, Trewia nudiflora and Vitex leucoxylon.

Out of the 68 shrubs identified 6 are restricted to the immediate boundary of the river. They are: *Homonoia riparia, Ochlandra scriptoria and Ochlandra travancorica. Pandanus furcatus, P. kaida* and *P. odorifer.*

Out of the 56 climbing plants identified, 27 are stragglers/woody climbers and 29 are slender climbers. Three woody climbing plants viz., *Derris trifoliate, Entada rheedei and Strychnos colubrine* are true riparian growing close to the Rivers

Out of the 470 species recorded from the study area of Chalakudiyar, 19 species (2 herbs, 3 shrubs, 14 trees) are cultivated species grown by the farmers along the banks of the river. The flora also consists of 51 exotic species of which 21 species are included in the 82 invasive species of Kerala identified by Sankaran et.al. (2013). 12 species out of the 19 cultivated plants are exotic species and it also include 1 invasive species listed by Sankaran et.al. (2013). The distribution pattern of the species with respect to its exotic/indigenous status is shown in Fig. 4.8.

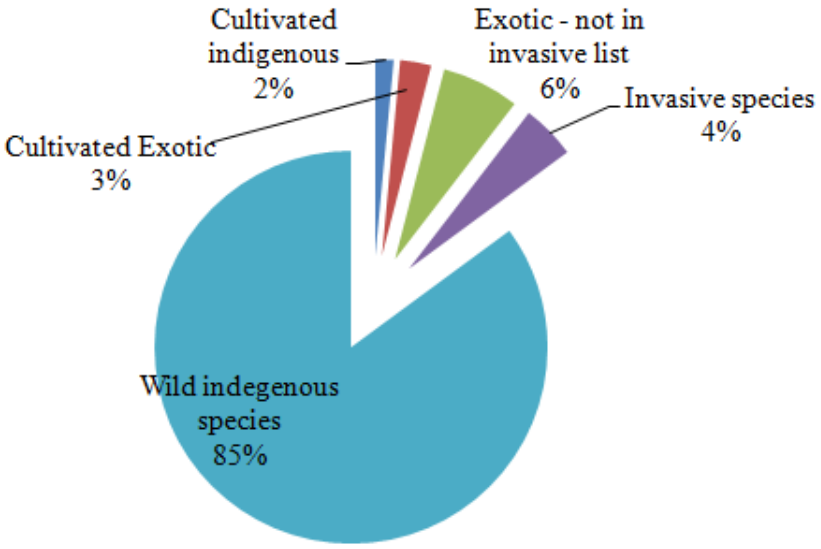

Fig. 4.8
Distribution Pattern of Floristic Elements in Chalakudiyar

4.1.1.4 Riparian Flora of Bharathappuzha

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.

The riparian flora consists of 346 Dicotyledons and 75 Monocotyledons. Out of these 36 species are cultivated by farmers along the banks of the river.

The largest family is Fabaceae with 38 species followed by Poaceae (33), Euphorbiaceae (27), Asteraceae (26) and Rubiaceae (23). Other large families with 10 or more species are: Scrophulariaceae (15), Acanthaceae (14), Cyperaceae (12), Convolvulaceae (10), and Lamiaceae (10). There are 40 families with only one species recorded from the area.

The riparian flora identified from the riparian region of Bharathapuzha tributaries consists of 213 herbaceous species, 88 trees, 68 shrubs and 52 climbers (71). The distribution pattern of the floristic elements is given in fig. 4.9.

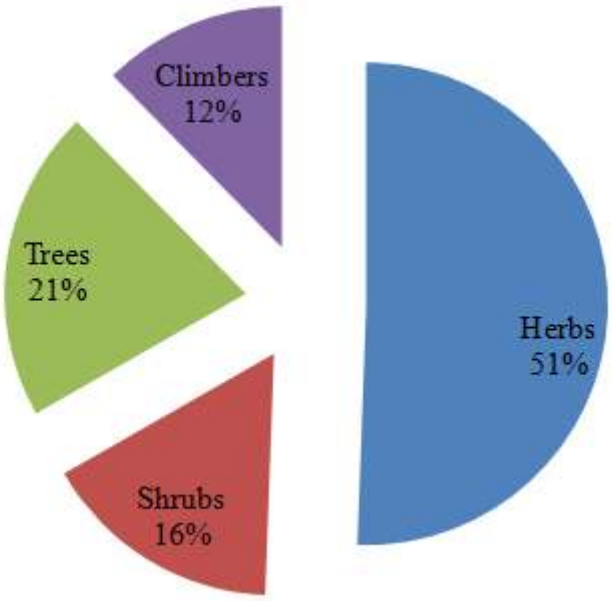

Fig. 4.9
Distribution Pattern of Floristic Elements in the Riparian Region of Bharathapuzha

Out of the 213 herbaceous species identified, 128 are annuals and remaining 85 are perennials. 32 herbaceous species aquatic or semi aquatic with distribution restricted to the running/stagnant water or water logged/wet areas like marshes, paddy fields etc. There is one parasitic herb also.

Out of the 307 tree species identified 28 are seen mostly in immediate banks of the River. They are: *Barringtonia acutangula, Barringtonia racemosa, Bruguiera cylindrical, Bruguiera gymnorrhiza, Ficus hispida, Hopea ponga, Ochreinauclea missionis* and *Trewia nudiflora.*

Out of the 68 shrubs identified 5 are seen to the immediate boundary of the river. They are: *Ficus heterophylla, Homonoia riparia, Ochlandra scriptoria, Pandanus furcatus* and *Pandanus palakkadensis.*

Out of the 52 climbing plants identified, 17 are stragglers/woody climbers and 35 are slender climbers.

Out of the 421 species recorded from the study area of Bharathapuzha, 33 species (4 herbs, 4 shrubs, 23 trees and 2 climbers) are cultivated species grown by the farmers along the banks of the river. The flora also consists of 97 exotic species of which 37 species are included in the 82 invasive species of Kerala identified by Sankaran et.al. (2013). 20 species out of the 33 cultivated plants are exotic species and it also include 3 invasive species listed by Sankaran et.al. (2013). the distribution pattern of the species with respect to its exotic/indigenous status is shown in Fig. 4.10.

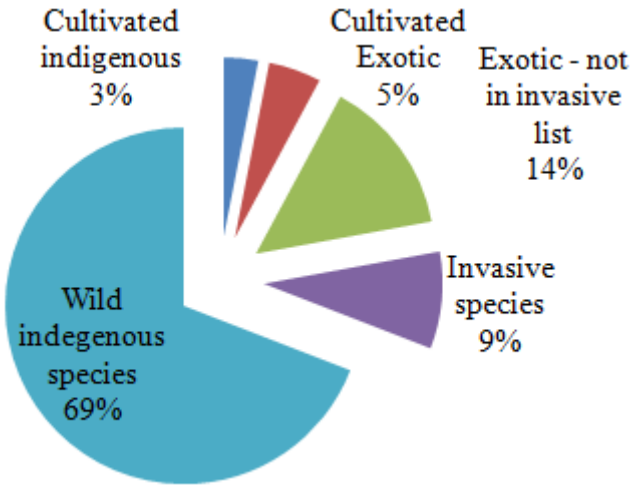

Fig. 4.10
Distribution Pattern of Floristic Elements in Bharathapuzha

4.1.2 Assessment of Species with respect to its Conservation Value

The plant other than the cultivated species which area 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 and the list is given as annexure III. 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 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 (Fig. 4.11).

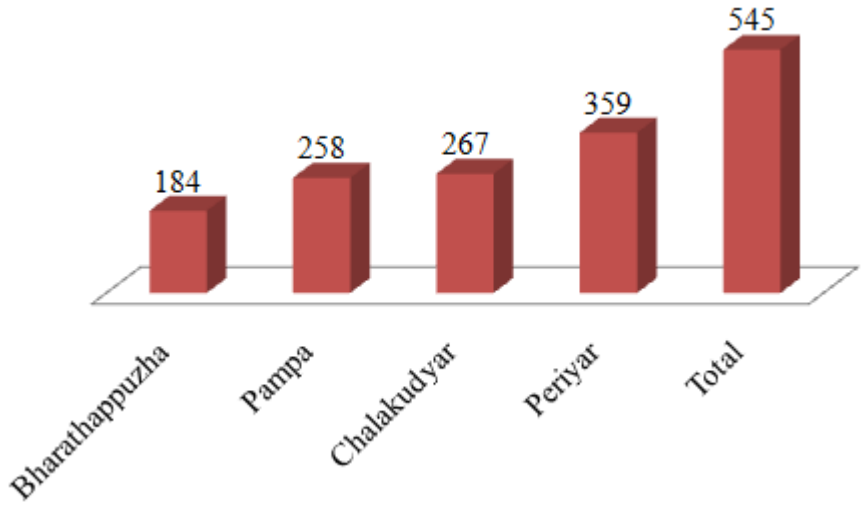

Fig. 4.11
Distribution Indigenous Species with High Conservation Value

4.1.2.1 Plants in IUCN Red List

The plants enlisted from the riparian areas of the four rivers under study were checked with latest version (2019-1) available at https://www.iucnredlist.org/. It is found that 40 plants are in the Red List Version 2019-1. Of these 4 are critically endangered (CR) viz. *Dipterocarpus bourdillonii, Ixora johnsonii, Syzygium travancoricum and Vateria indica;* 13 endangered and 23 in vulnerable category (Annexure III).

The distribution pattern of IUCN Red listed species in the four Rivers are given in Fig. 4.12.

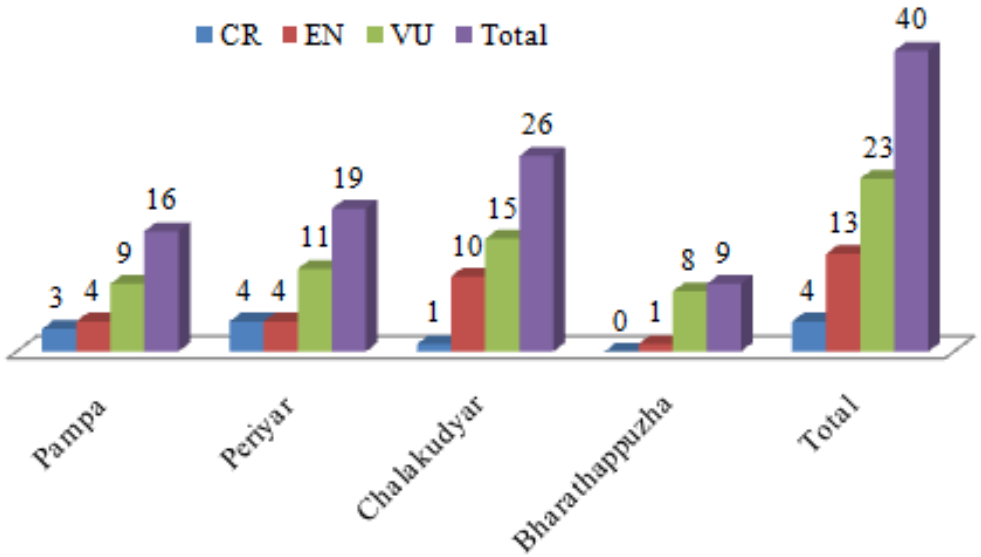

Fig. 4.12
Distribution Pattern of IUCN Red listed species in the Four Rivers

All the 4 critically endangered species are seen in Periyar riparian area. None of the species found in the area studied in Bharathapuzha. *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.

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. *Hopea ponga* is reported from all the four riparian regions under study. *Humboldtia vahliana* is seen in three rivers (Pampa, Periyar and Chalakudy), *Garcinia imberti* is seen in two rivers (Pampa and Chalakudy), *Aporosa bourdillonii* and *Hopea glabra* are seen only in Periyar region, 6 species (*Diospyros crumenata, Dipterocarpus indicus, Dysoxylum malabaricum, Syzygium bourdillonii , Syzygium chavaran* and *Atuna travancorica*) are found only in Chalakudy region and one species *Tarenna monosperma* is found only in Pampa.

Out of the 23 vulnerable species identified, the highest number is seen in Chalakudy River with 15 species, followed by Periyar (11), Pampa (9) and Bharathapuzha (8). Three species (*Ochreinauclea missionis, Hydnocarpus pentandrus I Dalbergia latifolia*) are reported from all the four riparian regions under study. Three species viz. *Arenga wightii, Mallotus atrovirens* and *Syzygium occidentale* are seen in three rivers (Pampa, Periyar and Chalakudy), Five species are seen in two rivers (*Ixora malabarica* and *Cayratia pedata* in Periyar and Bharathapuzha; *Diospyros paniculata*and *Garcinia wightii* in Pampa and Chalakudy and *Cinnamomum riparium* in Periyar and Chalakudy). 11 species are recorded only from one river (*Casearia wynadensis, Eriocaulon pectinatum* and *Santalum album* in Bharathapuzha; *Cinnamomum sulphuratum, Myristica malabarica, Orophea uniflora, Salacia beddomei, Saraca asoca* and *Garcinia indica* in Pampa and *Pterospermum reticulatum* and *Willisia selaginoides* in Periyar).

4.1.2.2 Endemic Plants

The riparian species identified and enlisted from the study regions of the four rivers were checked with the latest literature, Nayar et.al (2014) and Sasidharan (2012), to find out the endemic elements in the riparian flora.

Out of the 1243 species identified from the riparian areas, 198 are found endemic to India. Of these 11 plants are endemic to Kerala, 92 to Southern Western Ghats (SWG), 55 Western Ghats (WG), 32 Peninsular India (PI) and the rest 8 species found all over in India. The names of the endemic plants are available in Annexure III.

The distribution pattern of Endemic species in the Four Rivers is shown in Fig. 4.13. The highest number of endemic species is found in Periyar riparian areas with 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) .

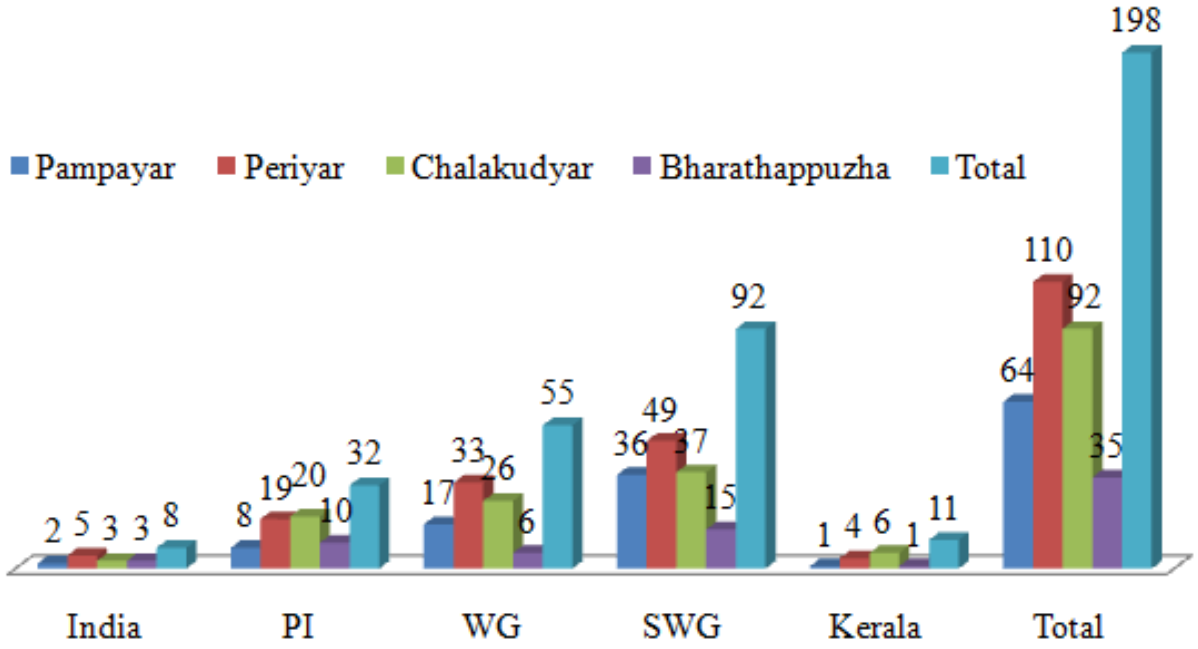

Fig. 4.13
Distribution Pattern of Endemic species in the Four Rivers

In Pampa there are 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).

Another analysis has shown that 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 three 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 136 species 10 are Kerala endemic, 64 Southern Western Gats, 39 Western Gats, 17 Peninsular India and 6 India endemic.

4.1.2.3 Medicinal Plants

Out of the 545indigenous 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 preparation and veterinary medicine. The details are given in annexure III. The distribution patterns of medicinal plants in the Four Rivers are shown in Fig. 4.14.

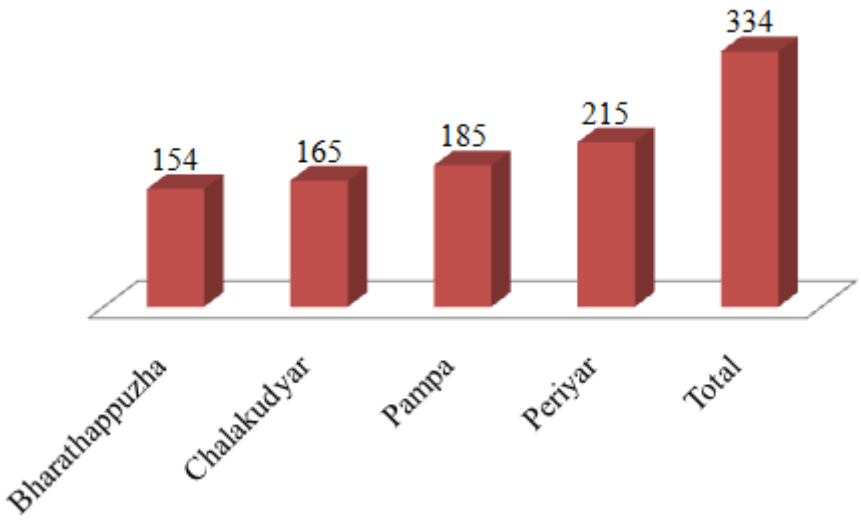

Fig. 4.14
Distribution Pattern of Medicinal Plants in the Four Rivers

The medicinal plants diversity is high Periyar (215species), followed by Pampa (185 species), Chalakudy (165 species) and lowest in Bharathapuzha (154 species).

It is also worth to mention that 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).

4.1.2.4 Plants having other Local Importance

Other major local uses of plants identified are plants which are used in local economic development activities like preparation of mats, handicrafts, etc. and wild plants collected for food preparations. It is also found that some plants are very much associated with the wild animals and fishes for its breeding, nesting and also the staple food. For example, it is noticed that *Malayannan* (Malabar giant squirrel) is high affinity to flowers and fruits of *Madhuca neriifolia*.

There are also several plants which are found to helping very much in checking river bank erosion, stabilizing banks, and controlling floods are also included in this category. Some plats locally very much important

for water purification also. The study has 214 such locally important plants from the riparian areas of four rivers under study. The details about its various uses are given in annexure III. The distribution pattern of plants with local importance in the Four Rivers is shown in Fig. 4.15.

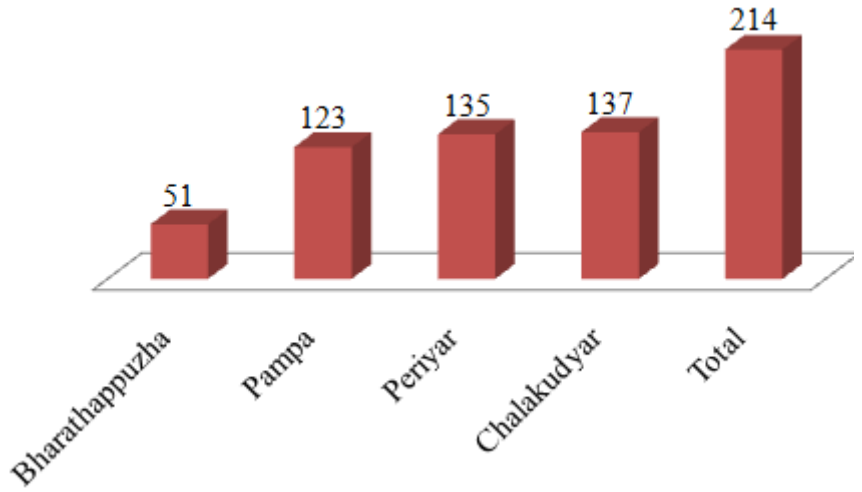

Fig. 4.15
Distribution Pattern of Plants having other Local Importance in the Four Rivers

Diversity plants having high local importance is highest in Chalakudy (137 species), followed by Periyar (135), Pampa (123) and lowest in Bharathapuzha (51species).

It is also worth mentioning that 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).

Photographs of some of the plats having high conservation value are given in plates 15 to 17.

4.2 IMPACT OF FLOOD/LANDSLIDE ON THE ECOSYSTEM

In order to assess the impact on the ecosystem, the study has mapped the different vegetation types in the riparian in the study area of the four Rivers before flood/landslide using Google Earth maps and prepared a base map. The physical impacts of the flood/landslide to the riparian areas were mapped using filed data and the two layers were then merged in single map. The maps are given as plates 9-A to 9-T (Pampayar), 10-A to 10-AM (Periyar), 11-A to 11-O (Chalakudiyar), 12-A to 12-M (Bharathapuzha –Thootha), 13-A to 13-E (Bharathapuzha –Gayathri) and 14-A to 12-E (Bharathapuzha –Kalpathi).

Based on the data received from the maps and filed data collection the impact of flood/landslide on the riparian ecosystem of four rivers is analysed.

4.2.1 Riparian Land Use

4.2.1.1 Pampayar

The details of river length covered in the study in Pa given in table 4.1.

Table 4.1
Details of Local bodies under the study area in Pampa River

Sl. No.	Name of Local Body	Length of River Ban (Km)		
		Right Bank	Left Bank	Total
Idukki District				
1.	Kumily (HL)	8.96	0.00	**8.96**
Kottayam District				
2.	Erumeli **(HL)**	4.40	0.00	**4.40**
Pathanamthitta District				
3	Seethathode(HL)	1.01	7.45	**8.46**
4	Chittar(HL)	8.79	19.18	**27.97**
5	Vechuchira(HL)	8.82	0.00	**8.82**
6	Naranammoozhi(HL)	0.00	9.81	**9.81**
7	Ranni-Pazhavangadi(HL)	7.41	0.00	**7.41**
8	Ranni-Perunnadu(HL)	0.00	4.82	**4.82**
9	Vadaserikkara(HL)	7.04	4.03	**11.07**
10	Ranni (HL)	0.00	7.24	**7.24**
11	Ranni-Angadi(HL)	3.24	0.00	**3.24**
12	Ayiroor (HL/ML)	8.08	0.00	**8.08**
13	Cherukole (H/MLL)	0.00	6.39	**6.39**
14	Kozhencherry (ML)	0.00	5.99	**5.99**
15	Thottapuzhassery (ML)	7.02	0.00	**7.02**
16	Mallappuzhassery	0.00	1.59	**1.59**
17	Aranmula (ML/LL)	0.00	5.59	**5.59**
18	Koipram(ML)	4.20	0.00	**4.20**
19	Kadapra (LL)	9.30	3.91	**13.21**
20	Niranam(LL)	1.60	0.00	**1.60**
Alappuzha District				
21	Chengannur Municipality (ML/LL)	5.40	5.88	**11.28**
22	Pandanadu (LL)	5.04	6.52	**11.56**
23	Thiruvanvandoor (LL)	1.46	0.00	**1.46**
24	Mannar (LL)	0.00	4.45	**4.45**
25	Veeyapuram(LL)	1.31	4.72	**6.03**
26	Cheruthana (LL)	5.87	5.80	**11.67**
27	Thakazhi (LL)	7.96	8.72	**16.68**
28	Champakulam(LL)	0.88	0.00	**0.88**
29	Nedumudi(LL)	11.01	0.00	**11.01**
30	Kainakary(LL)	7.22	0.00	**7.22**
31	Ambalapuzha South(LL)	2.95	0.00	**2.95**
32	Ambalapuzha North(LL)	0.00	2.32	**2.32**
33	Punnapra South(LL)	0.00	3.44	**3.44**
34	Punnapra North(LL)	0.00	8.39	**8.39**

HL-Highland, ML- Midland, LL-Lowland

Out of the 128 Km River stretch surveyed during the study, 56 Km is in the highland area, 23 Km in midland and remaining 49 Km in lowland area. The study area covered 34 Local bodies/BMCs (33 Grama Panchayats and 1 Municipality) in 4 districts.

The top ten local bodies with highest distance of river bank under it are: i) Chittar (28 km), ii) Thakazhi (16.7 km), iii) Kadapra (13.2km), iv) Cheruthana (11.7km), v) Pandanadu (11.6km), vi) Chengannur Municipality (11.3km), vii) Vadaserikkara (11.1km), viii) Nedumudi (11km), ix) Naranammoozhi (9.8km) and x) Kumily (9 km).

There are 11 local bodies having both right and left banks inside at least for some areas. They are: Seethathode, Chittar, Naranamoozhi, Ranni-Pazhavangadi, Vadasserikkara, Kadapra, Chengannur, Pandanad, Veeyapuram, Cheruthana and Thakazhi. In all other cases either left bank or right bank of the River is under the local body boundary.

The details of different land use classes in the riparian areas in given in table 4.2.

Table 4.2
Details of land use classes in the riparian regions of Pampa River

No.	Local Body	Natural vegetation		Mixed Tree crops		Paddy field		Barren/ built up		Rubber plantation		Total (km)
		RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	
1	Kumily	8657	0					300				**8.96**
2	Seethathode	620	3788		1030			391	2630			**8.46**
3	Chittar	3400	9916	3239	6348				400	2150	2520	**27.97**
4	Erumely			2696				900	0	800		**4.40**
5	Vechoochira			7300				600		920		**8.82**
6	Naranam moozhi		2200		5010						2600	**9.81**
7	Ranni-Perunnadu				3841				180		800	**4.82**
8	Ranni-Pazhavangadi			5562				180		1670		**8.11**
9	Vadaserikkara			6126	3512			230	120	680	400	**11.07**
10	Ranni				5747				1010		480	**7.24**
11	Ranni-Angadi			2940						300		**3.24**
12	Ayiroor			7723				160		200		**8.08**
13	Cherukole				5970				150		270	**6.39**
14	Kozhencherry				5750				240			**5.99**
15	Thottapuzhassery			6650				200		170		**7.02**
16	Mallappuzhassery				1440				150			**1.59**
17	Aranmula				4942				650			**5.59**
18	Koipram			3500				700				**4.20**
19	Kadapra			8850	3060			450	850			**13.21**
20	Niranam			1600								**1.60**
21	Chengannur			5020	5188			380	690			**11.28**
22	Pandanadu			4122	5512			920	1010			**11.56**

No.	Local Body	Natural vegetation		Mixed Tree crops		Paddy field		Barren/ built up		Rubber plantation		Total (km)
		RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	
23	Thiruvanvandoor			1360				100				**1.46**
24	Mannar				3695				750			**4.45**
25	Veeyapuram			1311	4220		200		300			**6.03**
26	Cheruthana			4070	3385	1700	1650	100	760			**11.67**
27	Thakazhi			3605	6770	3500	1800	850	150			**16.68**
28	Champakulam			540		160		180				**0.88**
29	Nedumudi			8410		700		1900				**11.01**
30	Kainakary			6973				250				**7.22**
31	Ambalapuzha South			2200		600		150				**2.95**
32	Amb. North				2224		100					**2.32**
33	Punnapra South				3043		300		100			**3.44**
34	Punnapra North				8090				300			**8.39**
Total (km)		**12.67**	**15.90**	**93.80**	**88.78**	**6.66**	**4.05**	**8.94**	**10.44**	**7.07**	**6.37**	**255.91**

The major land use class is mixed tree crops, followed by natural vegetation, barren land, rubber and paddy (Fig. 4.16). Mixed tree crops in the riparian areas of the River are present in almost all localbodies except Kumily. 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.

Continuos 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 ans Ranni GP. The high distribution of barren areas needs special attention by BMCs while developing action plans of rejuanation of the river.

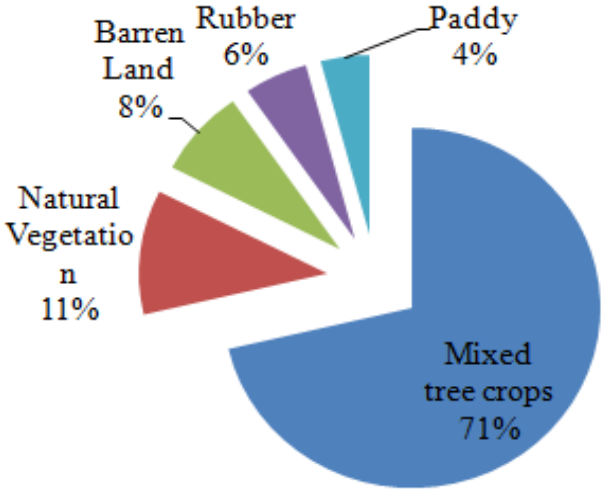

Fig. 4.16
Distribition of land use classes in the riparian regions of Pampa River

Rubber Plantations are seen on thee banks in 12 local body areas and are predominant in Chittar, Naranaamoozhi, Ranni-pazhavangadi, Vadasserikkara and Vechhoochira GPs. Paddy fields on banks of the river is present in eight lowland panachayts starting from Viyyapuram to Punnapara south and Punnapra North.

4.2.1.2 Periyar

Out of the 206 km of the River stretch studied, Periyar 28 km is in high highland (above 700 m from MSL) , 103 km in highland (75-700 m), 36 km in midland (8-75 m) and 39 km in lowland (below 8 m) area. The study area includes 44 BMCs (41 Grama Panchayats and 3 Municipalities) in 3 districts (Idukki, Ernakulam and Thrissur). The details of the local bodies coming under the study are given in table 4.3.

Table 4.3
Details of Local bodies under the study area in Periyar

Sl. No.	Name of Local Body	Length of River Ban (Km)		
		Right Bank	Left Bank	Total
Idukki District				
1	Kumily (HL)	12.8	0.0	**12.8**
2	Vandiperiyar(HL)	0.0	8.5	**8.5**
3	Elappara(HL)	0.0	6.7	**6.7**
4	Upputhara(HL)	0.0	11.5	**11.5**
5	Ayyappankovil(HL)	13.6	0.0	**13.6**
6	Vazhathoppu(HL)	3.9	3.1	**7.0**
7	Udumbannur(HL)	0.0	26.7	**26.7**
8	Vathikudy	12.4	0.0	**12.4**
9	Konnathadi(HL)	1.6	4.0	**5.6**
10	Vellathooval(HL)	3.6	0.0	**3.6**
11	Adimali(HL)	27.8	0.0	**27.8**
12	Karimannur (HL)	0.0	2.6	**2.6**
13	Vannappuram (HL)	0.0	4.0	**4.0**
Ernakulam District				
14	Kuttampuzha(HL)	40.1	22.7	**62.8**
15	Kavalangad(HL)	0.0	17.1	**17.1**
16	Keerampara(HL)	0.0	5.9	**5.9**
17	Ayyampuzha(HL)	11.8	0.0	**11.8**
18	Pindimana(HL/ML)	0.0	3.5	**3.5**
19	Vengoor(HL/ML)	0.0	12.5	**12.5**
20	Malayattur-Neeleswaram(HL/ML)	10.3	0.0	**10.3**
21	Koovappady (ML)	0.0	12.4	**12.4**
22	Kalady(ML)	4.4	0.0	**4.4**
23	Okkal(ML)	0.0	7.6	**7.6**
24	Kanjoor(ML)	9.2	0.0	**9.2**
25	Perumbavoor (ML)*	0.0	1.4	**1.4**
26	Sreemoolanagaram (ML)	8.6	0.0	**8.6**
27	Vazhakkulam(ML)	0.0	4.9	**4.9**
28	Keezhumadu(ML)	0.0	5.9	**5.9**

Sl. No.	Name of Local Body	Length of River Ban (Km)		
		Right Bank	Left Bank	Total
29	Aluva*	4.5	10.0	**14.5**
30	Chengamanadu(ML)	5.5	0.0	**5.5**
31	Nedumbassery(ML)	0.7	0.0	**0.7**
32	Kunnukara(LL)	5.8	0.0	**5.8**
33	Karumaloor(LL)	0.0	10.5	**10.5**
34	Puthenvelikkara(LL)	9.2	3.5	**12.7**
35	Chendhamangalam (LL)	0.0	4.0	**4.0**
36	Vadakkekara(LL)	0.0	3.4	**3.4**
37	Pallipuram(LL)	0.0	2.0	**2.0**
38	Kadungalloor(LL)	8.7	0.0	**8.7**
39	Choornikara (LL)	0.0	2.1	**2.1**
40	Eloor(LL)	0.0	9.8	**9.8**
41	Alangadu(LL)	2.9	0.0	**2.9**
42	Varappuzha(LL)	2.8	0.0	**2.8**
Thrissur District				
43	Kodungallur (LL)*	5.4	0.0	**5.4**
44.	Eriyad (LL)	3.9	0.0	**3.9**

***** *Municipality*

The top ten local bodies having highest distance of river bank under it are: i) Kuttampuzha (62.8km), ii) Adimali (27.8km), iii) Udumbannur (26.7km), iv) Kavalangad (17.1km), v) Aluva Municipality (14.5km), vi) Ayyappankovil (13.6km), vii) Puthenvelikkara (12.7km), viii) Vengoor (12.5km), ix) Vathikudy (12.9km), and x) Upputhara (11.5 km). There are only four local bodies where the river flowing through it with both right and left banks are there in the local body. They are: Vazhathoppu, Kuttampuzha, Aluva Municipality and Puthenvelikkara. In all other cases either left bank or right bank of the River is under the local body boundary. The details of different land use classes in the riparian areas in given in table 4.4. The major land use class is mixed tree crops, followed by natural vegetation, barren/built up land, rubber plantation, tea plantation, mixed vegetable crops, coffe plantation and paddy (Fig. 4.17).

Mixed tree crops in the riparian areas of the Periyar comes to about 44% of the area under study and are present in 36 localbodies. 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 natiraul vegetation (30%). Continous patches of nautural 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.

Table 4.4
Details of land use classes in the riparian regions of Periyar

No.	Local Body	Natural vegetation		Mixed Tree crops		Tea plantation		Barren land		Paddy		Coffee plantation		Rubber plantation		Mixed vegetables		Coconut		Total (km)
		RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	
1	Kumily			4843		5505		1620				852								12.8
2	Vandiperiyar						6978		1502											8.5
3	Elappara				3784		2907													6.7
4	Upputhara				6435		4417		621.8											11.5
5	Ayyappancoil			7734		3661						2195								13.6
6	Vazhathope	1298.4	1637	2272	1253				165.2	321.7										6.9
7	Udumbannoor		16583		10113															26.7
8	Vathikkudy			11080				421.4		938.2										12.4
9	Konnathady			1605	3991															5.6
10	Vellathooval	3558.8																		3.6
11	Adimali	27820																		27.8
12	Karimannoor		2580																	2.6
13	Vannapuram		3959																	4.0
14	Kuttampuzha	27234	12898		6389			895.8	694.9					11957	2717					62.8
15	Kavalangade		5451		7890				351						3371					17.1
16	Keerampara		3045												2894					5.9
17	Ayyampuzha	6173.4		1809										3801						11.8
18	Pindimana				3475															3.5
19	Vengoor		9583		2961															12.5
20	Malayattoor-Neeleswaram	1316.5		5738				2126						1154						10.3
21	Koovappady		3163		7067				870.7						1270					12.4
22	Ockal			3191				1191												4.4
23	Perumbavoor Municipality				6779				793											7.6

No.	Local Body	Natural vegetation		Mixed Tree crops		Tea plantation		Barren land		Paddy		Coffee plantation		Rubber plantation		Mixed vegetables		Coconut		Total (km)
		RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	
24	Kalady			7468				503.5								1198				**9.2**
25	Kanjoor				852				550											**1.4**
26	Sreemoolanagaram			5538				1478		1589										**8.6**
27	Vazhakkulam				1896				3044											**4.9**
28	Keezhmad								5935											**5.9**
29	Aluva Municipality			1387	3262			1582	6770	845						686.1				**14.5**
30	Chengamanad			4879												664.4				**5.5**
31	Nedumbassery			728																**0.7**
32	Kunnukara			5521				275.2												**5.8**
33	Karumalloor				9225				792.3								500			**10.5**
34	Puthenvelikara			9499	3158															**12.7**
35	Chendamangalam				3840												141			**4.0**
36	Vadakkekkara				3353															**3.4**
37	Pallippuram				472.5				1504											**2.0**
38	Kadungallur			4248				4449												**8.7**
39	Choornnikkara				1112				971											**2.1**
40	Eloor				5065				4441										341	**9.8**
41	Alangad			2901																**2.9**
42	Varapuzha			2581				198												**2.8**
43	Kodungalloor Municipality			4506				837.7												**5.3**
44	Eriyad			1970				1903												**3.9**
Total (km)		**67.4**	**58.9**	**89.5**	**92.4**	**9.2**	**14**	**17.5**	**29.0**	**3.7**	**0.0**	**3.0**	**0.0**	**16.9**	**10**	**2.5**	**0.6**	**0.0**	**0.3**	**416**

RB-Right Bank; LB-Left Bank

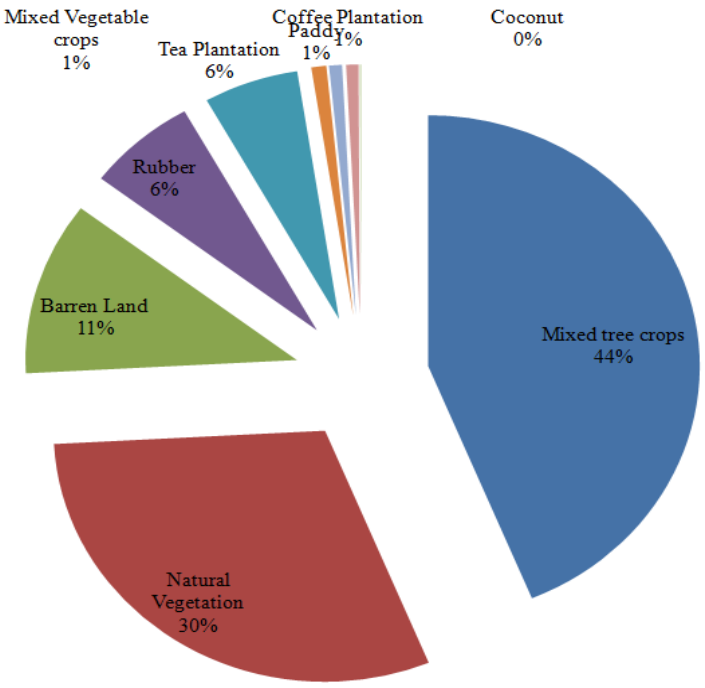

Fig. 4.17
Distribition of land use classes in the riparian regions of Periyar River

Barren/built up riparian areas present in 11% of the total lenth aand 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.

Rubber Plantatiopns on the banks of the River are seen in 6 local body areas viz. Kuttampuzha, Ayyampuzha, Kavalangad, Keerampara, Koovapady and Malayttur-Neeleswaram GPs. Tea Plantatiopns on the banks of the River are seen in 5 local body areas viz. Vandipperiyar, Upputhara, Ayyappancoil, Elappara and Kumily GPs. Coffee plantations on riparian areas are found in Ayyappancoil and Kumily GPs and paddy cultivation in Sreemoolanagarm and Vathikudy GPs

Cultivation of mixed vegetable crops on riparian areas is noticed in three local bodies viz. Chengamanad, Kanjoor and Vannapuram. Continuos patches of coconut alone is seen only in Ellor GP.

4.2.1.3 Chalakudyar

Out of the 79 km of the River stretch studied, 45 km is in the highland (75-700 m), 33 km in midland (8-75 m) and 2 km in lowland (below 8 m) area. The study area includes 13 BMCs (12 Grama Panchayats and 1 Municipality) in 2 districts (Thrissur and Ernakulam) as detailed in table 4.5.

Table 4.5
Details of Local bodies under the study area in Chalakudyar

Sl. No.	Name of Local Body	Length of River Ban (Km)		
		Right Bank	Left Bank	Total
Thrissur District				
1	Athirappilly (HL)	35.4	16.2	**51.6**
2	Pariyarm (HL/ML)	12.2	0.0	**12.2**
3	Meloor (ML)	0.0	15.7	**15.7**
4	Chalakudy MPTY (ML)	9.4	0.0	**9.4**
5	Mala	0.7	0.0	**0.7**
6	Kadukutty	5.0	9.2	**14.2**
7	Annamanada	5.3	3.7	**9.0**
8	Parakkadavu	4.5	6.9	**11.4**
9	Kuzhur	5.1	0.0	**5.1**
Ernakulam District				
10	Ayyampuzha	0.0	22.2	**22.2**
11	Manjapra	0.0	0.9	**0.9**
12	Karukutti	0.0	1.7	**1.7**
13	Puthenvelikkara	2.1	8.0	**10.1**

The top five local bodies having highest distance of river bank under it are: i) Athirappilly (51.6), ii) Ayyampuzha (22.2km), iii) Meloor (15.7km), iv) Kadukutty (14.2km) and v) Pariyaram (12.2), There are five local bodies viz. Athirappilly, Kadukutty, Annamanada, Parakkadavu and Puthenvelikkara, where the river is flowing through it with both right and left banks inside the GP area. In all other cases either left bank or right bank of the River is under the local body boundary.

The details of different land use classes in the riparian areas in given in table 4.6. The major land use classes are mixed tree crops, followed by natural vegetation, oil palm, Teak plantation, barren/built up land, rubber plantation and coconut plantation (Fig. 4.18).

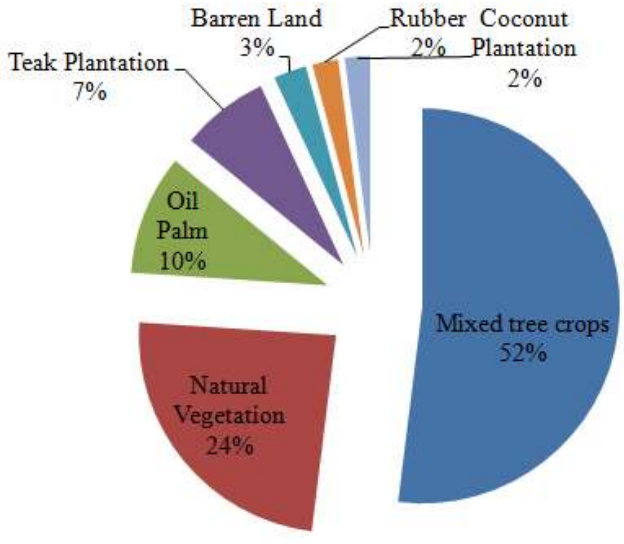

Fig. 4.18
Distribition of land use classes in the riparian regions of Chalakudyar

Table 4.6
Details of land use classes in the riparian regions of Chalakudy River

No.	Local Body	Natural vegetation		Mixed Tree crops		Teak plantation		Barren land		Coconut plantation		Oil palm plantation		Rubber plantation		Total (km)
		RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	
1	Athirappilly	15606	11461	637		7091	4724	1078		1242		9722				**51.6**
2	Pariyarm	205		8260				1559		2175						**12.2**
3	Meloor				15334				396							**15.7**
4	Chalakkudy			8302				1083								**9.4**
5	Mala			685												**0.7**
6	Kadukutty			5029	9180											**14.2**
7	Annamanada			5290	3701											**9.0**
8	Parakkadavu			4198	6860			307								**11.4**
9	Kuzhur			5100												**5.1**
10	Ayyampuzha		12220										6450		3481	**22.2**
11	Manjapra				864											**0.9**
12	Karukutti				1664											**1.7**
13	Puthanvelikkra			2141	8016											**10.1**
Total (km)		**15.81**	**23.68**	**39.64**	**39.70**	**7.09**	**4.72**	**4.03**	**0.40**	**3.42**	**0.00**	**9.72**	**6.45**	**0.00**	**3.48**	**164.0**

RB-Right Bank; LB-Left Bank

Mixed tree crops in the riparian areas of the Chalakudiyar comes to more than half of the area under study and are present in almost all the local bodies areas except Ayyampuzha GP. Puthenvelikkara, Meloor, Kadukutty, Annamanada, Chalakudy and Parakkadavu are the top local bodies under this category. Continous patches of nautural vegetation on the banks are only in Athirappilly and Ayyampuzha which are predominantly under forests. Oil palm plantations are also found only in these two GPs. Teak plantation by the foresr department is restricted to Athirapilly GP.

Continuous barren/built up areas are present in five local bodies viz. Pariyaram, Athirapilly, Meloor, Chalakudy and Parakkadavu. GP. Rubber Plantations on the banks of the River are seen in only in Ayyampuzha GP and Coconut in Athirapilly GP only.

4.2.1.4 Bharathapuzha

Out of the 136 km of the River stretch studied, the entire stretch of Kalpathippuzha (26 km) and 15 km out of 80 km in Thoothappuzha is in the highland area (75-700 m). The remaining areas of Kalpathi and Thootha and the entire stretch of Gayathrippuzha are in the midland area (8-75 m). The study area covers 35 BMCs; 7 Grama Panchayats and 1 Municipality in Kalpathippuzha, 8 Grama Panchayats and 1 Municipality in Gayathrippuzha and 18 Grama Panchayats in Thoothappuzha (Total 33 Grama Panchayats and 2Municipalities), in 3 districts (Palakkad, Thrissur and Malappuram). The details are given in table 4.7.

Table 4.7
Details of Local bodies under the study area in Bharathappuzha

Sl. No.	Name of Local Body	Length of River Ban (Km)		
		Right Bank	Left Bank	Total
Palakkad District				
1	Puthussery (HL)	4.36	6.34	10.70
2	Marutha Road (HL)	5.63	5.23	10.86
3	Palakkad Municipality (HL)*	2.67	5.43	8.10
4	Malampuzha (HHL/HL)	2.05	0.00	2.05
5	Akathethara (HL)	0.68	0.00	0.68
6	Puthuppariyaram (HL)	4.77	0.00	4.77
7	Pirayiri (HL)	0.00	4.62	4.62
8	Parali (HL/ML)	4.61	4.57	9.18
9	Vadakkancherry (HL/ML)	4.18	2.37	6.55
10	Kannampra (HL/ML)	0.00	5.01	5.01
11	Kavassery(HL/ML)	9.52	0.00	9.52
12	Puthucode (ML)	0.00	5.02	5.02
13	Tharur (HL/ML)	3.45	0.00	3.45
14	Ottappalam Municipality (ML)*	2.88	0.00	2.88
15	Kumaramputhur (HHL/HL/ML)	14.82	5.76	20.58
16	Mannarkkad (HHL/HL/ML)	0.00	9.77	9.77
17	Karimpuzha (ML)	12.93	3.85	16.78
18	Sreekrishnapuram (ML)	0.00	6.21	6.21

Sl. No.	Name of Local Body	Length of River Ban (Km)		
		Right Bank	Left Bank	Total
19	Vellinezhi (ML)	0.00	7.99	7.99
20	Thachanattukara(HL/ML)	4.58	0.00	4.58
21	Cherplassery (ML)	0.00	9.23	9.23
22	Nellaya (ML)	0.00	3.71	3.71
23	Kulukkallur (ML)	0.00	9.69	9.69
24	Vilayur (ML)	0.00	9.62	9.62
25	Thirvegappura (ML)	0.00	10.72	10.72
26	Paruthur (ML)	0.00	2.84	2.84
27	Aanakkara (ML)	0.00	1.85	1.85
Thrissur District				
28	Pazhayannoor (HL/ML)	0.00	8.70	8.70
29	Thiruvilwamala (ML)	10.36	0.00	10.36
30	Kondazhy (HL/ML)	0.00	8.23	8.23
Malappuram District				
31	Aaliparambu (ML)	10.34	0.00	10.34
32	Elamkulam (ML)	9.53	0.00	9.53
33	Pulamanthole (ML)	9.83	0.00	9.83
34	Moorkkanad (ML)	5.45	0.00	5.45
35	Irimpiliyam (ML)	12.79	0.00	12.79

***** *Municipality*

The top eight local bodies having more than 10 km of river bank under it are: i) Kumaramputhur (20.58km), ii) Karimpuzha (16.78km), iii) Irumpliyam (12.79km), iv) Marutha Road (10.86), v) Thiruvegappura (10.72), vi) Puthuussery (10.7) and vii) Thiruvillamala (10.36) and Aliparampa ((10.34).

There are 7 local bodies where the river flowing through it with both right and left banks inside it. They area Puthuussery, Marutha Road, Palakkad Municipality and Parali in Kalpathippuzha; Vadakkancherry in Gayathrippuzha and Kumaramputhur and Karimpuzha in Thoothappuzha., In all other cases either left bank or right bank of the River is under the local body boundary.

The details of different land use classes in the riparian areas in given in table 4.8. The major land use classes are mixed tree crops, followed Coconut plantation, barren/built up land, natural vegetation, Paddy, Rubber plantation and mixed vegetable crops (Fig. 4.19).

The mixed tree crop areas in the Bharathapuzha riparian zone comes to more than half of the area under study and are present in almost all the local bodies areas except Tharoor GP and Ottappalam Municipality area. Irumpliyam, Pulamanthole, Thiruvegappura, Karimpuzha, Elamkulam, Aliparampa, Vilayur, Kulukkallur and Kumaramputhur are the top local bodies under this category. Coconut plantations on the banks are seen in 25 out of the 35 local bodies under study.

Table 4.4
Details of land use classes in the riparian regions of Bharathappuzha River

No.	Local Body	Natural vegetation		Mixed Tree crops		Paddy		Barren land		Coconut plantation		Mixed Vegetables		Rubber plantation		Total (km)
		RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	RB (m)	LB (m)	
Kalpathippuzha																
1	Puthussery			1897	2110			2356	3390	110	416		423			**10.70**
2	Marutha road			2243	2396			2912	2108	478	723					**10.86**
3	Palakkad Municipality			852	2358			1613	3009	203	64					**8.10**
4	Malampuzha			866				495		690						**2.05**
5	Akathethara			154				531								**0.68**
6	Puthupariyaram			1407		26		2926		408						**4.77**
7	Pirayari				1399		491		2346		386					**4.62**
8	Parli			2251	1159	95	133	2057	1481	202	1799					**9.18**
Gayathrippuzha																
9	Vadakkancherry			2522	281			746	587	914	1505					**6.55**
10	Kannampra				3268				1093		644					**5.01**
11	Kavasserry			3435				2101		3980						**9.52**
12	Puthukkod				2527				512		1978					**5.02**
13	Pazhayannur				2971				1719		3773				240	**8.70**
14	Tharur							694		2752						**3.45**
15	Thiruvilamala			261				2703		7400						**10.36**
16	Kondazhi				1126				2379		4723					**8.23**
17	Ottappalam Municipality							1022		1858						**2.88**

Thoothappuzha																
18	Kumaramputhur	820	474	6830	342			754		6134	4941			281		**20.58**
19	Mannarkkad		3732		713				212		5109					**9.77**
20	Karimpuzha	2256	2183	7803	583			821		902	1087	324		821		**16.78**
21	Sreekishnapuram				5744						469					**6.21**
22	Vellinezhi				6650				1341							**7.99**
23	Thachanattukara			3384		1193										**4.58**
24	Aaliparambu	468	0	7834		371		547		1121						**10.34**
25	Cherpulasserry				2619		876		348		5383					**9.23**
26	Nellaya				1650		2058									**3.71**
27	Elamkulam			8251		1280										**9.53**
28	Kulukkallur		625		7223		382				1458					**9.69**
29	Pulamanthol			9825												**9.83**
30	Vilayur				7523				329		1764					**9.62**
31	Moorkkanad			5446												**5.45**
32	Thiruvegappura				8654		468				1602					**10.72**
33	Irumpliyam			12786												**12.79**
34	Paruthur				2477								366			**2.84**
35	Aanakkara				1852											**1.85**
Total (km)		**3.54**	**7.01**	**78.05**	**65.6**	**2.97**	**4.41**	**22.3**	**20.9**	**27.15**	**37.82**	**0.32**	**0.79**	**1.10**	**0.24**	**272.17**

RB-Right Bank; LB-Left Bank

High concentrations are in Kumaramputhur, Thiruvillamala, Cherpulassery, Mannarkkad, Kondazhi, Kavassery, Pazhayannur and Tharur GPs.

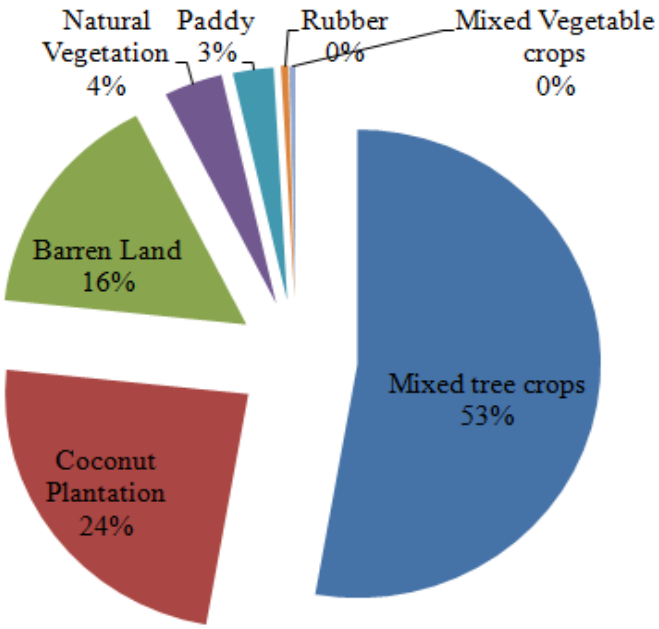

Fig. 4.19
Distribition of land use classes in the riparian regions of Bharathapuzha

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.

Paddy cultivation on the immediate banks of the river is seen in 10 out of the 35 local bodies studied. Highest GPs are Nellaya, Elamkulam, Thachanattukara and Cherpulassery. Mixed vegetable crop cultivation is noticed in Puthussery, Paruthur and Karimpuzha GPs and Rubber Plantations in Karimpuzha, Kumaramputhur and Pazhayannur GPs.

4.2.2 Physical Impact of Flood/ Landslide

The major physical impact of the flood and landslide in the riparian areas are erosion and deposition on the banks. The eroded and deposited areas under various categories are mapped and shown in plates 9 to 14.

4.2.2.1 Pampayar

The maps showing eroded/deposited areas are given in plates 9-A to 9-T. The local body wise details river length where erosion was happened is shown in Table 4.9.

Photographs of some eroded areas are given plate 18.

Table 4.9
Local body wise details River Bank Erosion in Pampayar

No.	Local Body Name	High			Medium			Low			Grand Total (Km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Vechoochira	2760		2760	1600		1600	1460		1460	**5.8**
2	Vadaserikkara		155	155	1600	1900	3500	1200		1200	**4.9**
3	Chittar	900	1080	1980	400	651	1051		1255	1255	**4.3**
4	Kadapra			0			0	1600	1536	3136	**3.1**
5	Erumely	1175	300	1475	870	512	1382			0	**2.9**
6	Naranammoozhi		800	800		270	270		1600	1600	**2.7**
7	Kozhencherry			0			0	1820		1820	**1.8**
8	Ranni-Pazhavangadi	925		925			0	839		839	**1.8**
9	Thottapuzhassery			0			0	1400		1400	**1.4**
10	Ranni			0		100	100		890	890	**9.9**
11	Pandanadu			0			0		900	900	**9.0**
12	Ayiroor			0	700		700			0	**7.0**
13	Seethathode			0		66	66	447		447	**5.1**
14	Ranni-Angadi			0	460		460			0	**4.6**
15	Kumily			0	317		317			0	**3.2**
16	Ranni-Perunnadu			0		300	300			0	**3.0**
Total (Km)		**5.7**	**2.3**	**8.1**	**5.9**	**3.8**	**9.75**	**8.77**	**6.18**	**14.9**	**32.8**

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. The distribution pattern of erosion is shown in Fig. 4.20.

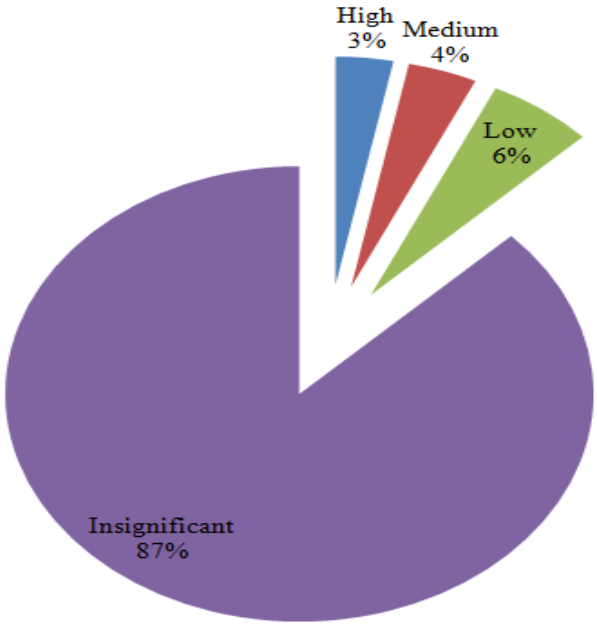

Fig. 4.20
Distribution Pattern of Bank erosion in Pampayar

The local bodies were more areas were eroded in the Pampayar are: Vechoochira, Vadaserikkara, Chittar, Kadapra, Erumely, Naranammoozhi, Kozhencherry and Ranni-Pazhavangadi. High scale erosions (bank eroded top to bottom) were happened mainly in Vechoochira, Chittar, Erumely and Ranni-Pazhavangadi Grama Panchayats. The major local bodies were medium scale erosions (around half portion from the top eroded) are Vadasserikkara, Vechoochira, Erumely and Chittar. Low erosions (top soil from the bank eroded) were predominant in Kadapra, Kozhencherry, Naranammoozhi, Vechoochira, Thottapuzhassery, Chittar and Vadaserikkara GPs.

An analysis of the overlaid map of Erosion on land use has shown that the banks with barren areas are highly eroded and with natural vegetation is less eroded. The most suited example for this is found in the Vechoochira GP.

The local body wise details river length where deposition has occurred is shown in Table 4.10.

Table 4.10
Local body wise details of sand/mud deposition in Pampayar

No.	Local Body Name	High			Medium			Low			Grand Total (Km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Chittar		6200	6200	7320	9000	16320	800	1200	2000	**24.5**
2	Vadaserikkara	3200	2800	6000	2200	1100	3300			0	**9.3**
3	Seethathode	800	4648	5448		2500	2500		300	300	**8.2**
4	Kumily	3827		3827	2480		2480	1650		1650	**8.0**
5	Ayiroor	2200		2200	5083		5083	800		800	**8.1**
6	Cherukole		2200	2200		4190	4190			0	**6.4**
7	Vechoochira	1700		1700	1200		1200	2750		2750	**5.7**
8	Thottapuzhassery	980		980	1600		1600	2100		2100	**4.7**
9	Ranni-Angadi	900		900	2340		2340			0	**3.2**
10	Ranni-Pazhavangadi	800		800	4812		4812			0	**5.6**
11	Erumely	700		700	3696		3696			0	**4.4**
12	Ranni-Perunnadu		700	700		3321	3321			0	**4.0**
13	Kadapra	300		300			0	9000	3910	12910	**13.2**
14	Cheruthana			0			0	5870	5795	11665	**11.7**
15	Pandanadu			0			0	5042	6522	11564	**11.6**
16	Chengannur Municipality			0			0	5400	5878	11278	**11.3**
17	Thakazhi			0			0	5655	4620	10275	**10.3**
18	Naranammoozhi			0		7610	7610			0	**7.6**
19	Veeyapuram			0		1200	1200	1311	3520	4831	**6.0**

No.	Local Body Name	High			Medium			Low			Grand Total (Km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
20	Aranmula			0			0		5592	5592	**5.6**
21	Ranni			0		4800	4800			0	**4.8**
22	Mannar			0			0		4445	4445	**4.4**
23	Koipram			0			0	4200		4200	**4.2**
24	Kozhencherry			0		2200	2200		500	500	**2.7**
25	Niranam			0			0	1600		1600	**1.6**
26	Mallappuzhassery			0			0		1590	1590	**1.6**
27	Thiruvanvandoor			0			0	1460		1460	**1.5**
Total (km)		**15.4**	**16.5**	**32.0**	**30.7**	**35.9**	**66.7**	**47.6**	**43.9**	**91.5**	**190**

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. The photographs of some of the sand/mud deposited areas are shown in plate 19. The distribution pattern of deposition is shown in Fig. 4.21.

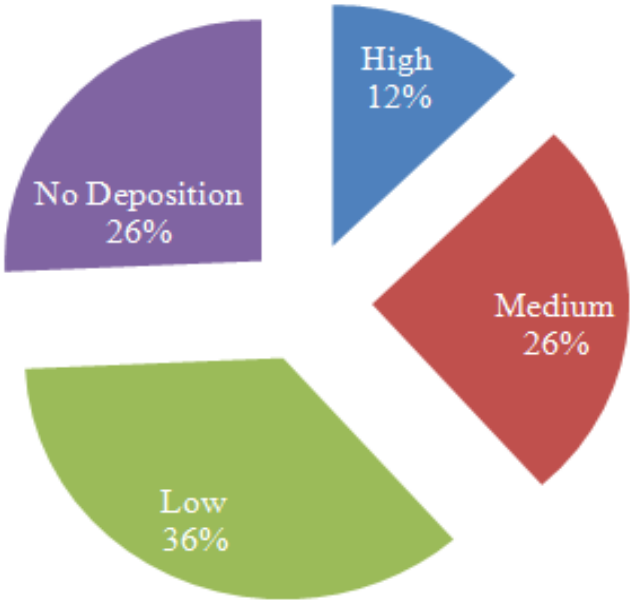

Fig. 4.21
Distribution Pattern of Sand/Mud Deposition on the Banks of Pampayar

Out of the 256 km stretch covered in the study, about 190 km is affected by sand/mud deposition in the banks as well as inside the River. Out of this 32 km is affected at a high scale with complete covering of the bank area at more than 1m height, There are 13 local bodies in this category of which most highly affected GPs are: Chittar, Vadaserikkara, Seethathode , Kumily, Cherukole and Vechoochira, About 67 km stretch in 16 local bodies is affected at medium scale with complete covering of the bank area at less than 1m height, The major local bodies in this category are: Chittar, Naranamoozhi, Ayiroor, Ranni-Pazhavangadi, Ranni, Cherukole Erumely, Ranni-Perunnadu and Vadasserikkara GPS. Low scale deposition with bank

covered with mud/sand at in a scattered manner is occurred in about 92 km stretch in 19 local bodies. The major local bodies in this category are: Kadapra, Cheruthana, Pandanad, Chengannur Municipality and Thakazhi.

4.2.2.2 Periyar

The maps showing eroded/deposited areas are given in plates 10-A to 10-AM. The photographs of erosion at selected location are given in plate 20. The local body wise details river length where erosion was happened is shown in Table 4.11.

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 pattern of erosion is shown in Fig. 4.22. High erosion is very prevalent here.

Table 4.11
Local body wise details River Bank Erosion in Periyar

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Vathikudy	7561		7561			0	782		782	**8.34**
2	Kumily	6285		6286			0			0	**6.29**
3	Udumbannur		4465	4465		1932	1932			0	**6.40**
4	Vazhathoppu	2480	1500	3980			0			0	**3.98**
5	Ayyappankovil	3550		3550			0			0	**3.55**
6	Vandiperiyar		3537	3537			0			0	**3.54**
7	Kuttampuzha	928	1646	2574			0		900	900	**3.47**
8	Elappara		2556	2556			0			0	**2.56**
9	Upputhara		1535	1535			0			0	**1.54**
10	Koovappady		981	981		1330	1330			0	**2.31**
11	Adimali	800		800	2521		2521	648		648	**3.97**
12	Kavalangad			0			0		3151	3151	**3.15**
13	Vellathooval			0			0	3017		3017	**3.02**
14	Vadakkekara			0			0		2511	2511	**2.51**
15	Vannappuram			0		2434	2434			0	**2.43**
16	Konnathadi			0		1446	1446			0	**1.45**
17	Pindimana			0		924	924			0	**0.92**
18	Okkal			0		670	670			0	**0.67**
19	Malayattur-Neeleswaram			0	285		285			0	**0.29**
Total (km)		**21.6**	**16.2**	**37.8**	**2.8**	**8.7**	**11.5**	**4.5**	**6.6**	**11.0**	**60.4**

The major local bodies were more areas were eroded in the Periyar are: Vathikudy, Udumbannur, Kumily, Vazhathoppu, Adimali, Ayyappankovil, Vandiperiyar, Kuttampuzha, Kavalangad and Vellathooval. The photographs of some of the eroded areas are shown in plate 20. High scale erosions were happened mainly in Vathikudy, Kumily, Udumbannur,

Vazhathoppu, Ayyappankovil and Vandiperiyar Grama Panchayats. The major local bodies were medium scale erosions re Adimali, Vannappuram, Udumbannur, Konnathadi and Koovappady. Low erosions were predominant in Kavalangad, Vellathooval, Vadakkekara and Kuttampuzha GPs.

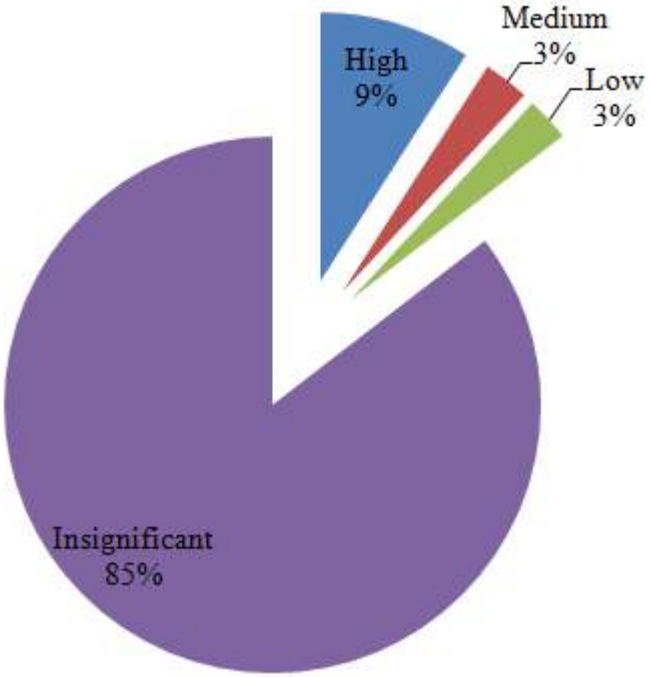

Fig. 4.22
Distribution Pattern of Bank erosion in Periyar

An analysis of the overlaid map of Erosion on land use has shown that the banks with barren areas are highly eroded and with natural vegetation is less eroded. The well-matched example for this is found in the Kumily and Vandiperiyar GPs.

The local body wise details river length where deposition has occurred is shown in Table 4.12.

Table 4.12
Local body wise details of sand/mud deposition in Periyar

No.	Local Body Name	High			Medium			Low			Grand Total (Km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Vengoor		6600	6600		4507	4507			0	**11.1**
2	Vandiperiyar		5145	5145			0			0	**5.1**
3	Kuttampuzha	3654	559	4213	9164	4309	13473	340		340	**18.0**
4	Adimali	3568		3568	5595		5595			0	**9.2**
5	Udumbannur		3435	3435		1297	1297			0	**4.7**
6	Ayyappankovil	2701		2701			0			0	**2.7**
7	Karimannur		2580	2580			0			0	**2.6**
8	Upputhara		2013	2013			0			0	**2.0**
9	Koovappady		1871	1871		3248	3248			0	**5.1**

No.	Local Body Name	High			Medium			Low			Grand Total (Km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
10	Malayattur-Neeleswaram	1800		1800	1463		1463	6608		6608	**9.9**
11	Elappara		1598	1598			0			0	**1.6**
12	Chendhamangalam		1463	1463		500	500			0	**2.0**
13	Kanjoor	1293		1293			0	4665		4665	**6.0**
14	Kumily	1293		1293			0			0	**1.3**
15	Vathikudy	1152		1152			0			0	**1.2**
16	Kavalangad		1001	1001		5875	5875			0	**6.9**
17	Kalady	945		945	890		890	1140		1140	**3.0**
18	Kodungallur Municipality	613		613			0			0	**0.6**
19	Aluva Municipality	510		510	5000		5000		410	410	**5.9**
20	Vannappuram		355	355			0			0	**0.4**
21	Okkal		266	266		2095	2095		1303	1303	**3.7**
22	Vadakkekara		260	260			0			0	**0.3**
23	Vazhathoppu	190		190			0			0	0.2
24	Ayyampuzha			0			0	11818		11818	11.8
25	Karumaloor			0		10518	10518			0	10.5
26	Kunnukara			0	5796		5796			0	5.8
27	Chengamanadu			0	4960		4960	583.5		584	5.5
28	Puthenvelikkara			0	2500		2500			0	2.5
29	Pindimana			0		2110	2110			0	2.1
30	Vazhakkulam			0		914	914		1184	1184	2.1
31	Sreemoolanagaram			0	1500		1500			0	1.5
32	Keezhumad			0			0		1189	1189	1.2
	Nedumbassery			0	680		680			0	0.7
Total (km)		**17.7**	**27.1**	**44.9**	**37.5**	**35.4**	**72.9**	**25.2**	**4.1**	**29.2**	**147**

The riparian areas of Periyar are also highly affected by mud/sand deposition on the banks. About 34% of the total distance under study and 33 out of the 44 local bodies studied were affected by sand/mud deposition at various scales. The photographs of some of the sand/mud deposited areas are shown in plate 21. The distribution pattern of deposition is shown in Fig. 4.23.

Out of the 416 km stretch covered in the study, about 147 km is affected by sand/mud deposition in the banks as well as inside the River. Out of this 45 km is affected at a high scale. There are 22 local bodies in the most highly affected category of which the major ones are: Vengoor, Kuttampuzha, Adimali, Udumbannur, Ayyappankovil and Upputhara. About 73 km

stretch is affected at medium scale. Out of the 19 local bodies in this category, the major ones are: Kuttampuzha, Karumaloor, Kavalangad, Adimali, Kunnukara, Chengamanadu, Aluva Municipality, Vengoor and Koovappady.

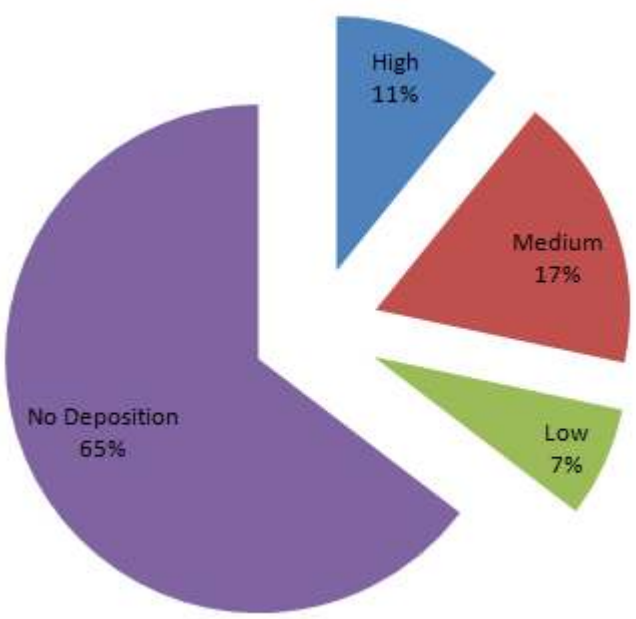

Fig. 4.23
Distribution Pattern of Sand/Mud Deposition in the Banks of Periyar

Low scale sand/mud deposition occurred in about 29 km stretch in 10 local bodies. The major local bodies in this category are: Ayyampuzha, Malayattur-Neeleswaram, Kanjoor and Okkal GPs.

4.2.2.3 Chalakudyar

The maps showing eroded/deposited areas are given in plates 11-A to 11-O. The photographs of erosion at selected location are given in plate 22. The local body wise details river length where erosion has occurred is shown in Table 4.13.

Table 4.13
Local body wise details River Bank Erosion in Chalakudyar

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Athirappilly	10020	7800	17820	22179	6567	28746	3152	1770	4922	**51.5**
2	Ayyampuzha		3430	3430		5742	5742		12418	12418	**21.6**
3	Meloor		6242	6242		6190	6190		3102	3102	**15.5**
4	Kadukutty			0	5029	8972	14001			0	**14.0**
5	Pariyarm			0	7238		7238	4914		4914	**12.2**
6	Chalakkudy			0	4686		4686	4690		4690	**9.4**
7	Parakkadavu			0			0	4361	1211	5572	**5.6**
8	Annamanada			0			0	5290		5290	**5.3**

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
9	Karukutti		1664	1664			0			0	**1.7**
10	Manjapra		864	864			0			0	**0.9**
11	Mala			0	685		685			0	**0.7**
Total (km)		**10.0**	**20.0**	**30.0**	**39.8**	**27.5**	**67.3**	**22.4**	**18.5**	**40.9**	**138.2**

Chalakudyar is also 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 pattern of erosion is shown in Fig. 4.24. The major local bodies were more areas were eroded in the Chalakudiyar are: Athirappilly, Ayyampuzha, Meloor, Kadukutty, Pariyarm and Chalakudy. High scale erosions were happened mainly in Athirappilly, Meloor, Ayyampuzha, Karukutti and Manjapra Grama Panchayats. The major local bodies were medium scale erosions are Athirappilly, Kadukutty, Pariyarm, Meloor, Chalakudy and Ayyampuzha. Low erosions were predominant in Ayyampuzha, Annamanada, Pariyarm, Parakkadavu, Athirappilly, Chalakudy, and Puthenvelikkara GPs.

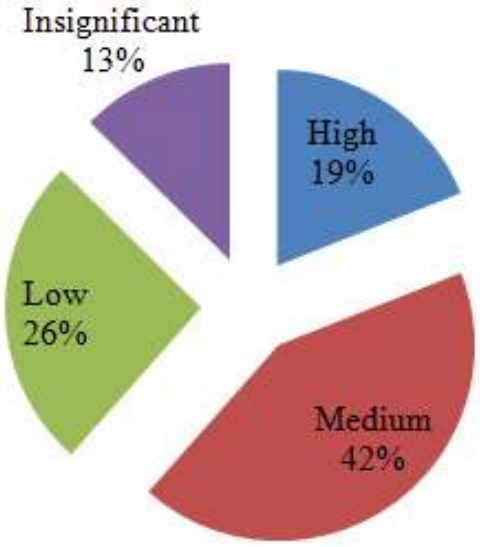

Fig. 4.24
Distribution Pattern of Bank erosion in Chalakudyar

The local body wise details river length where deposition has occurred in Chalakudyar is shown in Table 4.14.

Table 4.14
Local body wise details of sand/mud deposition in the banks of Chalakudyar

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Athirappilly	2270	3170	3170	4850		4850		1650	1650	**9.7**
2	Ayyampuzha			0		4743	4743			0	**4.7**
3	Puthenvelikkara			0			0	2141.5		2141.5	**2.1**

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
4	Parakkadavu			0		430	430			0	**0.4**
Total (km)		**3.2**	**3.2**	**3.2**	**4.9**	**5.2**	**10.0**	**2.1**	**1.7**	**3.8**	**17.0**

The riparian areas of Chalakudy River are comparatively less affected by mud/sand deposition on the banks. About 11% of the total distance under study and 4 out of the 13 local bodies studied were affected by sand/mud deposition at various scales. The photographs of some of the sand/mud deposited areas are shown in plate 23. The distribution pattern of deposition is shown in Fig. 4.25.

Out of the 162 km stretch covered in the study, about 17 km is affected by sand/mud deposition in the banks as well as inside the River. Out of this 3.2 km is affected at a high scale and this area is in the Athirappilly GP. About 10 km stretch in three local bodies viz. Athirappilly, Ayyampuzha and Parakkadavu is affected at medium scale. Low scale deposition with bank covered with mud/sand at in a scattered manner has occurred in about 3.8km stretch in 2 local bodies, viz. Puthenvelikkara and Athirappilly.

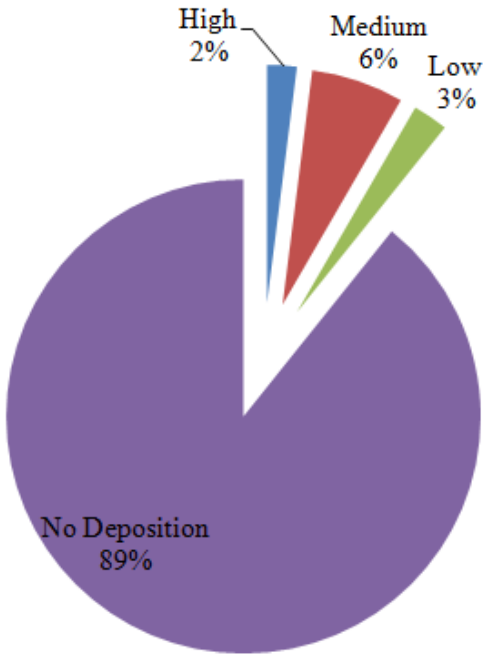

Fig. 4.25
Distribution Pattern of Sand/Mud Deposition in the Banks of Chalakudyar

4.2.2.4 Bharathapuzha

The maps showing eroded/deposited areas are given in plates 12-A to 12-M (Thootha), 13-A to 13-E (Gayathri) and 14-A to 14-E (Kalpathi). The photographs of erosion at selected location are given in plate 24. The local body wise details river length where erosion has occurred is shown in Table 4.15.

Table 4.15
Local body wise details River Bank Erosion in Bharathapuzha

No.	Grama Panchayat	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Mannarkkad		1526	1526		4737	4737			0	**6.3**
2	Pazhayannoor			0		4569	4569		1504	1504	**6.1**
3	Thiruvegappura			0		4832	4832			0	**4.8**
4	Cherplassery			0		2357	2357		2184	2184	**4.5**
5	Puthukkad			0		1540	1540		2723	2723	**4.3**
6	Aaliparambu			0	4102		4102			0	**4.1**
7	Thiruvillamala			0	3198		3198	851		851	**4.0**
8	Kavassery			0	2565		2565		1482	1482	**4.0**
9	Kannampra			0		2904	2904		955	955	**3.9**
10	Irumpliyam	1036		1036	2331		2331	350		350	**3.7**
11	Paruthur			0		1808	1808		1681	1681	**3.5**
12	Karimpuzha			0			0		3369	3369	**3.4**
13	Vilayur			0		1089	1089		2035	2035	**3.1**
14	Sreekrishnapuram			0		2850	2850			0	**2.9**
15	Pirayiri		2644	2644			0			0	**2.6**
16	Kondazhy			0		1368	1368		1250	1250	**2.6**
17	Tharur			0	2337		2337			0	**2.3**
18	Kulukkallur			0		2314	2314			0	**2.3**
19	Marutha road			0	2089		2089			0	**2.1**
20	Moorkkanad			0	756		756	1142		1142	**1.9**
21	Vadakkancherry			0	670	970	1640			0	**1.6**
22	Nellaya			0			0		1400	1400	**1.4**
23	Puthuppariyaram	1265		1265			0			0	**1.3**
24	Elamkulam			0	1170		1170			0	**1.2**
25	Kumaramputhur	366		366	638		638			0	**1.0**
26	Aanakkara		808	808			0			0	**0.8**
27	Pulamanthole			0	640		640			0	**0.6**
28	Parli	277	287	564			0			0	**0.6**
29	Akathethara	380		380			0			0	**0.4**
30	Malampuzha	314		314			0			0	**0.3**
Total (km)		**3.6**	**5.3**	**8.9**	**20.5**	**31.3**	**51.8**	**2.3**	**18.6**	**20.9**	**81.7**

Bharathapuzha is comparatively the least affected River by bank erosion. About 30% of the total distance under study and 30 out of the 35 local bodies studied were affected by River bank erosion. However, the high scale erosion is comparatively less (3%). The pattern of erosion is shown in Fig. 4.26.

The photographs of some of the eroded areas are given in plate 18.

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.

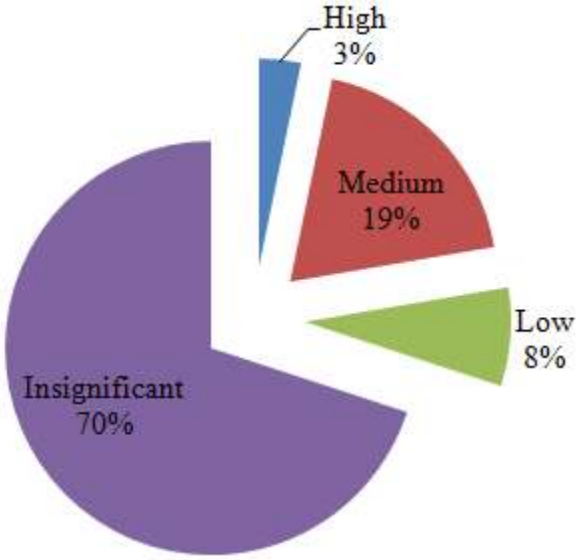

Fig. 4.26
Distribution Pattern of Bank erosion in Bharathapuzha

High scale erosions were mainly occurred in Pirayiri and Puthuppariyaram (Kalpathi) and Mannarkkad and Irumpliyam (Thootha) Grama Panchayats. The major local bodies were medium scale erosions are Thiruvegappura, Mannarkkad and Aliparampa (Thootha) and Pazhayannoor and Thiruvillamala (Gayathri). Low erosions were predominant in Karimpuzha, Cherplassery, Vilayur and Paruthur (Thootha) and Puthukkad, Pazhayannoor and Kavassery (Gayathri), GPs.

The local body wise details river length where deposition has occurred in Bharathapuzha during flood/land slide is shown in Table 4.16.

Table 4.16
Local body wise details of sand/mud deposition in the banks of Bharathappuzha

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
1	Kumaramputhur	1833		1833	4239		4239		1327	1327	**7.4**
2	Aanakkara		1419	1419			0			0	**1.4**
3	Mannarkkad		415	415	1187	1189	2376			0	**2.8**
4	Thiruvegappura			0		8187	8187			0	**8.2**
5	Karimpuzha			0	2018		2018	5655		5655	**7.7**
6	Parli			0	2654		2654	1137	1900	3037	**5.7**
7	Pulamanthole			0	811		811	4041		4041	**4.9**
8	Vellinezhi			0		3185	3185		1040	1040	**4.2**
9	Thachanattukara			0	3952		3952			0	**4.0**
10	Aaliparambu			0	3951		3951			0	**4.0**

No.	Local Body Name	High			Medium			Low			Grand Total (km)
		RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	RB (m)	LB (m)	Total (m)	
11	Palakkad Municipality			0	2046	735	2781		440	440	**3.2**
12	Puthuppariyaram			0	2696		2696			0	**2.7**
13	Kavassery			0			0	2349		2349	**2.3**
14	Cherplassery			0			0		2287	2287	**2.3**
15	Vilayur			0		835	835		1169	1169	**2.0**
16	Thiruvillamala			0	852		852	934		934	**1.8**
17	Elamkulam			0	951		951	574		574	**1.5**
18	Sreekrishnapuram			0		1330	1330			0	**1.3**
19	Ottappalam Municipality			0	1289		1289			0	**1.3**
20	Vadakkanchery			0		793	793			0	**0.8**
21	Marutha road			0			0		657	657	**0.7**
22	Malampuzha			0	580		580			0	**0.6**
23	Akathethara			0	350		350			0	**0.4**
Total (km)		**1.8**	**1.8**	**3.7**	**27.6**	**16.3**	**43.8**	**14.7**	**8.8**	**23.5**	**71.0**

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 23out of the 35local bodies studied were affected by sand/mud deposition at various scales. Out of this, major portion is in Thootha tributary (19%), followed by Kalpathi (5%) and Gayathri (2%). The photographs of some of the sand/mud deposited areas are shown in plate 25. The distribution pattern of deposition is shown in Fig. 4.27.

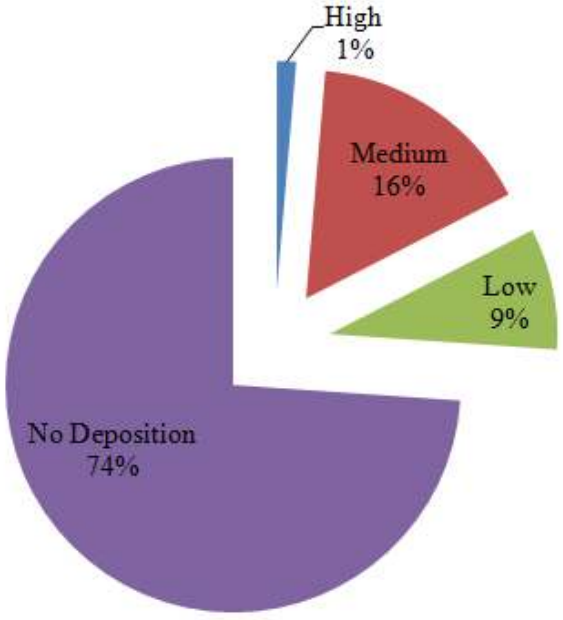

Fig. 4.27
Distribution Pattern of Sand/Mud Deposition in the Banks of Bharathapuzha

Out of the 272 km stretch covered in the study, 71 km (52km in Thootha, 13km in Kalpathi and 6km in Gayathri) is affected by sand/mud deposition in the banks as well as inside the River. Out of this 3.7 km is affected at a high scale in the three GPS of Thootha tributary, Kumaramputhur, Aanakkara and Mannarkkad. 43.7 km stretch in 19 GPs (11 in Thootha, 5 in Kalpathi and 3 in Gayathri) is affected at medium scale deposition. The major ones (Thiruvegappura, Kumaramputhur, Thachanattukara, Aliparampa and Vellinezhi) are again in Thootha tributary. Low scale deposition has occurred in 23.5 km stretch in 12 local bodies (7 in Thootha, 3 in Kalpathi and 2 in Gayathri). The major GPs in this category are: Karimpuzha, Pulamanthole and Cherplassery in Thootha tributary, Parali in Kalpathi and Kavassery in Gayathri.

4.2.3 Waste Deposition on Banks

One of the major impact on the riparian ecosystem due to flood is deposition of inorganic wastes, mainly plastics on the trees and other vegetation causing damage to the species and ecosystem. This phenomenon is noticed in all the Rivers. The study has not attempted to quantify the waste generated in each River and a detailed analysis of the issue due to shortage of time and funding.. Some photographs of waste deposition in different Rivers are given in plates 26 and 27.

4.3 IMPACT OF FLOOD/LANDSLIDE ON RIPARIAN FLORA

4.3.1 Species Loss

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. Cultivated species in the riparian areas were damaged mainly due to highly turbid water retained in the area for three to four days and the soil condition is changed. Selected photographs showing the loss is given in different rivers are given in plates 28 to 31.

The study has revealed that 604 species are affected by flood/landslide in various rivers. The species affected are shown in annexure II.

It found that 60% of the plants f the plants affected are herbs (Fig.4.28), followed by shrubs and trees (15%) and climbers (10%).

The number of species affected and not affected during the flood/landslide in the four rivers studied is shown in Fig. 4.29. Out of the 604 species partially damaged during the flood/landslide event, 359 species (around 60%) are partially damaged 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 (mentioned in annexure II as regenerated/spread to more area). Many of these plants are exotic species (108 numbers). Out of these 76 plants, mostly exotic/invasive species were even spread to more locations.

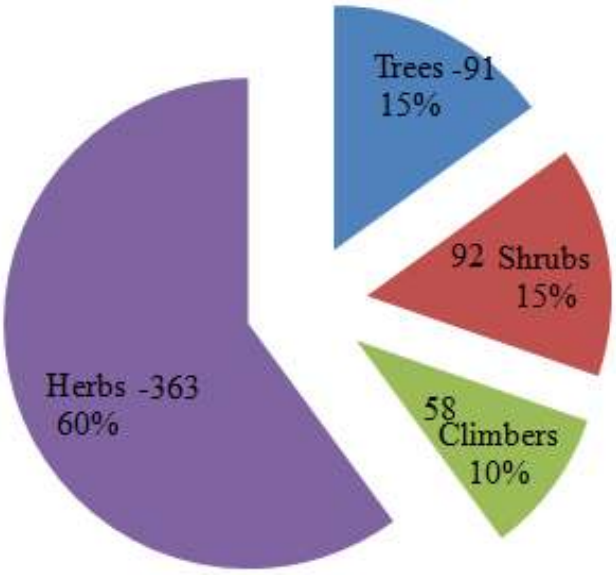

Fig. 4.28
Species Composition of Plats affected by flood/landslide in four Rivers

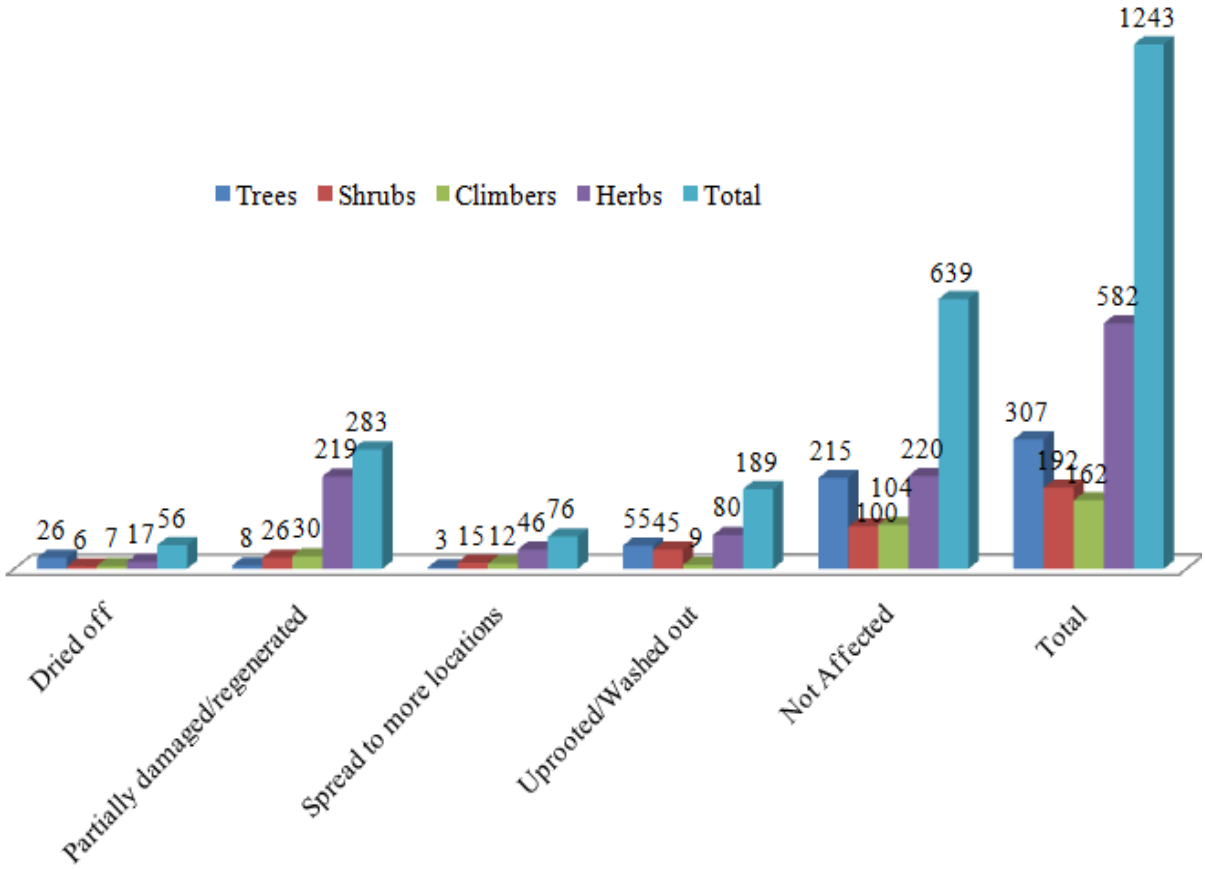

Fig. 4.29
Number of species affected/not affected by flood/landslide in four Rivers

There are 56 species which has dried after this. Most of them are cultivated species (43 species). Plants belongs to 189 species has uprooted and washed out during the flood. All these plants are growing close to the bank and were happened mainly due to bank erosion. In many instances, large trees uprooted in landslide in the up streams coming in high velocity was collided with the trees and damaged or uprooted it also.

However, it is found that all the species which has damaged in one place is found in other areas of the same River and 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 we were not able to see it there 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.

The impact on the flora is also analysed for each Rivers under study and is shown in Fig. 4.30.

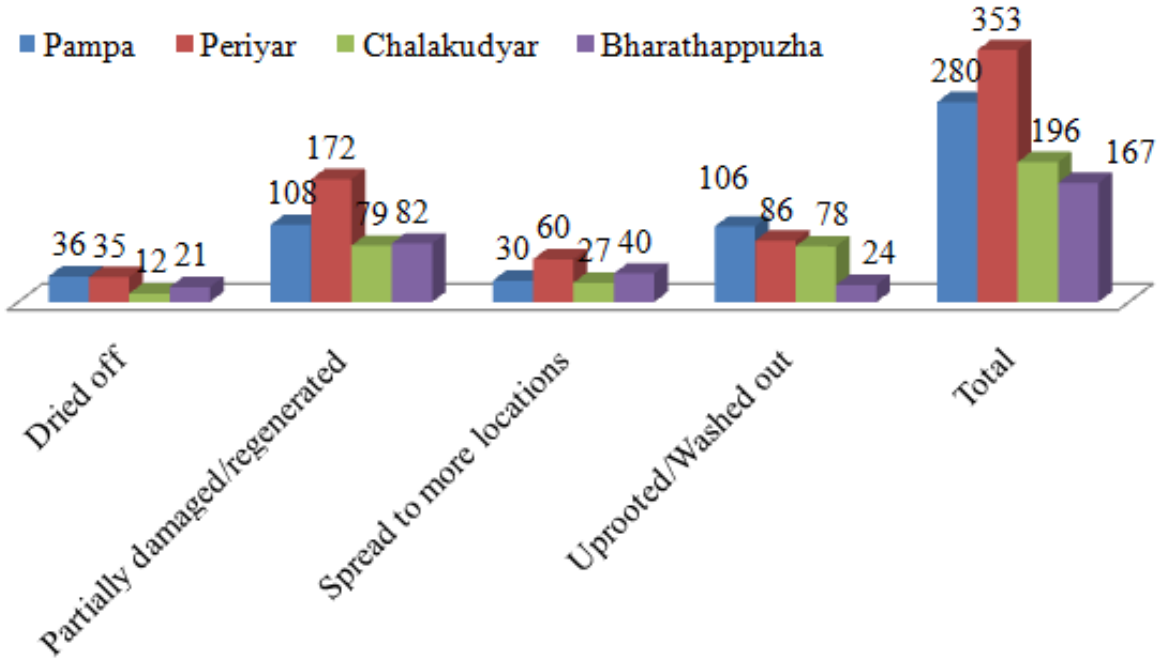

Fig. 4.30
River wise species affected by flood/landslide

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 highest 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 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.

4.3.2 Loss of Species with high Conservation Value

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 found lost in some places. The result of the analysis in the four rivers under study is given in Fig. 4.31.

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 n Bharathappuzha with 3 species.

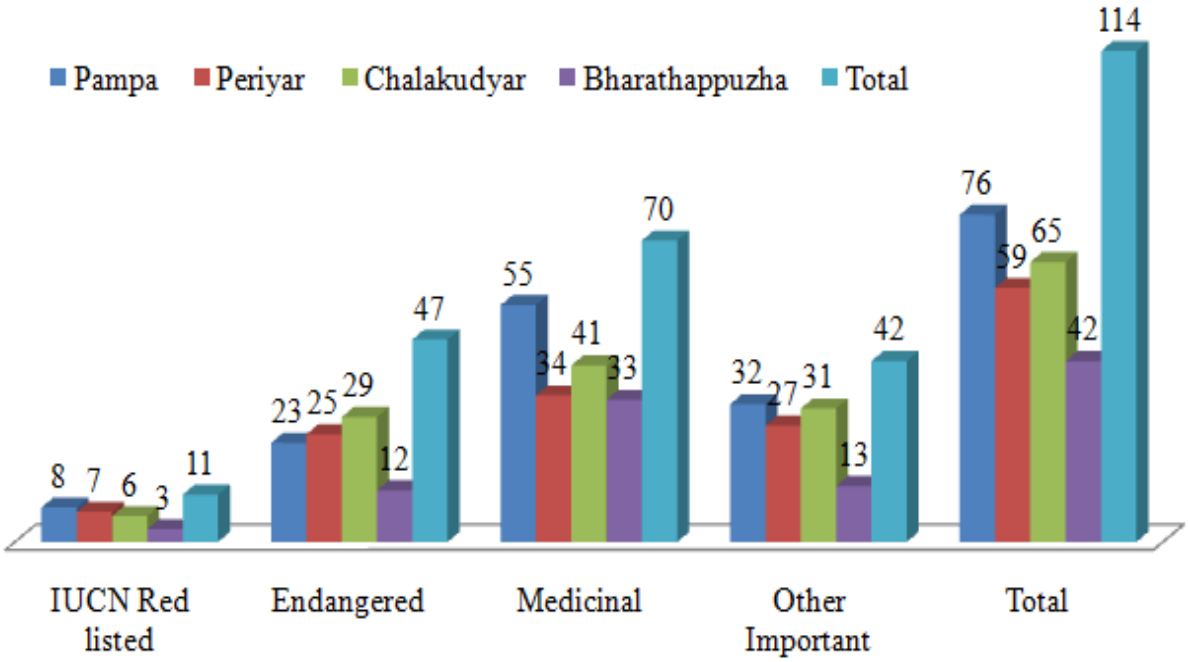

Fig. 4.31
River wise species of High Conservation value affected by flood/landslide

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 n Bharathappuzha with 12 species.

It is found 70 out of the 334 medicinal plant species were affected by the flood/landslide. Here also the highly affected River is Pampa with 55 species followed by Chalakudy (41 species), Periyar (34 species) and Bharathappuzha with 33 species.

In the case of the locally important plant species, 42 out of the 214 species identified by the study was affected in one or other Rivers. The highly affected here is also Pampa (32 species), followed by Chalakudy (31 species), Periyar (27 species) and Bharathappuzha (13 species)

4.3.3 Spread of Invasive species

One of major impact of the August 2018 flood/landslide in Kerala to the riparian ecosystem/vegetation is the spread of many invasive plants listed by a recent study by Sankaran et.al. (2013) published by the Kerala State Biodiversity Board. 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 (plates 23 to 26).

India has adopted the Aichi Target 9 as its National Biodiversity Target 4 – i.e., to identify invasive alien species and their pathways of introduction, and to develop strategies to manage prioritised invasive alien species by 2020. Hence it is found as important to discuss biodiversity conservation challenges posed by invasive species in the riparian areas after the flood situation. The study by Sankaran et.al. (2013) has listed 82 plants as invasive species of Kerala in four categories viz. High Risk (A Category) - 20 species, Medium Risk (B Category) -22 species, Low Risk (C Category) -14 species and Insignificant (D Category) - 26 species.

The present study has identified 48 out of the 82 plants as invasive species of Kerala from the riparian areas of four Rivers (Fig. 4.32). The High Risk (A Category) consists of 13 out of the 20 species in Kerala, Medium Risk (B Category) with 14 out of the 22 species in Kerala, Low Risk (C Category) with 13 out of the 14 species in Kerala and Insignificant (D Category) with 13 out of the 26 species in Kerala.

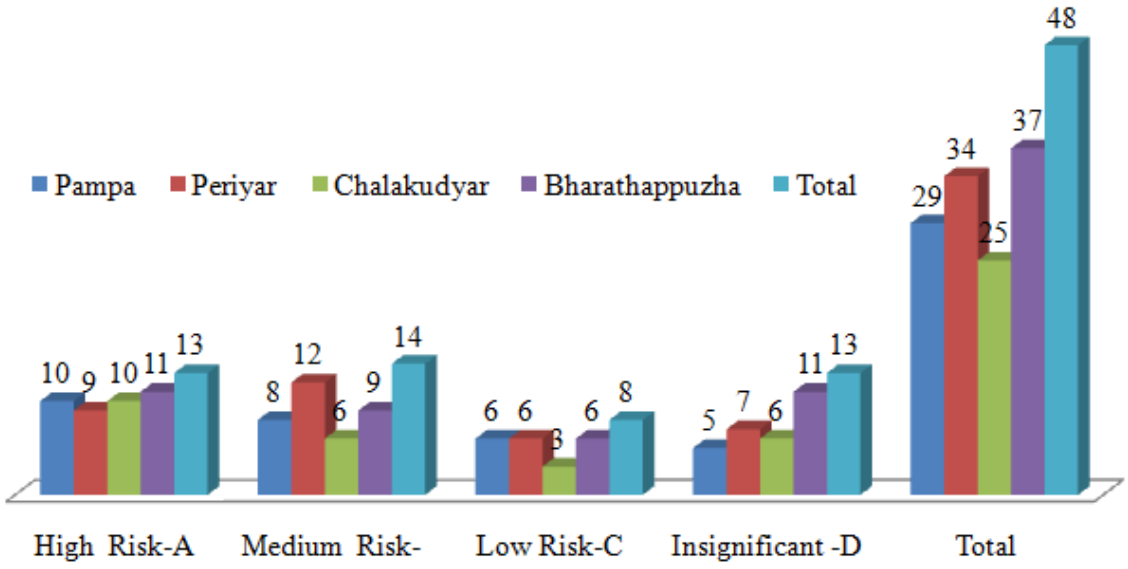

Fig. 4.32
River wise distribution of invasive species in four Rivers

River wise analysis has shown that Bharathapuzha is the 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). This is 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). There are 29 invasive species (10 species under A category, 8 species under B category, 6 species under C category and 5 species under A category) from the riparian areas of Pampayar The Chalakudy River is the lease 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.

4.4 IDENTIFICATION OF POTENTIAL SPECIES FOR RIVER BANK AFFORESTATION

4.4.1 Criteria for Prioritization of Species

One of the objectives of the present investigation is to identify potential riparian species for afforestation activities in the riparian ecosystem in Kerala. The study has identified 545 plants having high conservation value based on various parameters (Annexure III). All these species can be used for various river bank afforestation purposes based on the utility of each plant mentioned. These parameters have to be considered while doing any afforestation programs. The current availability of the species in various rivers and its geographical distribution (Lowland, Midland, and Highland), its habit etc. is available from Annexure II.

In order to identify the plants having highest conservation value, the study has prioritised these 545 plants by assigning values to each criteria identified as given Table 4.17.

Table 4.17
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**

Based on the scores obtained to each species five categories of species were identifiedas shown below:

Score > 35 - Very High Priority

Score 28- 35- High Priority

Score 20- 27- Medium Priority

Score 12- 19- Low Priority

Score >12- Insignificant and excluded from the prioritised list

4.4.2 Species Prioritized for Afforestation Programs

Accordingly, the study has identified a total of 288 species (169 trees, 43 shrubs, 54 herbs and 22 climbers) under 4 prioritised classes and the details these plants and its distribution under various physiogeographical areas of the four rivers under study is given in Annexure IV.

There are 14 species in the very high category, 69 in high category, 158 in medium priority and another 47 species in the low priority category. The habit wise distribution of species prioritised for future afforestation programs is shown in Fig. 4.33 and the number of species in each category in different Rivers under study is shown in Fig. 4.34.

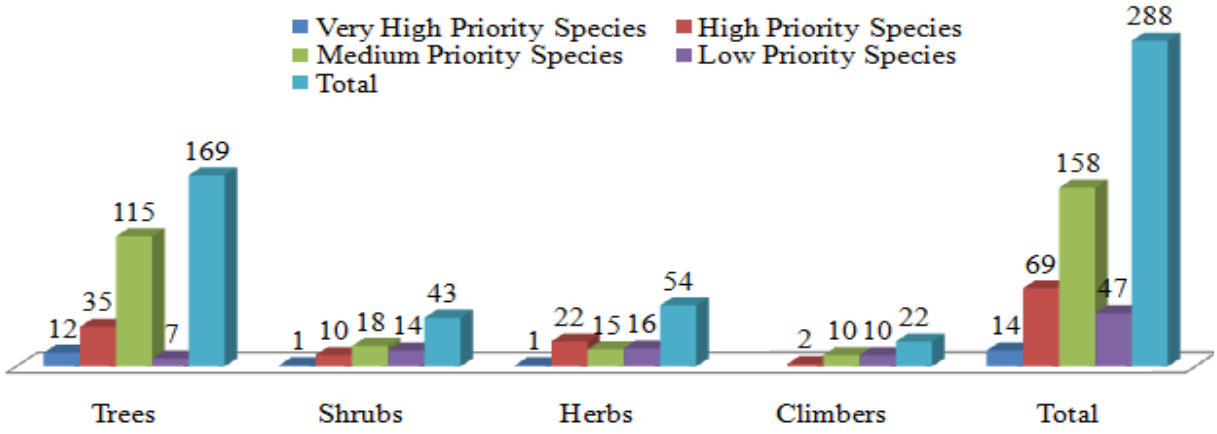

Fig. 4.33
Habit wise number of species prioritised for River Bank Afforestation

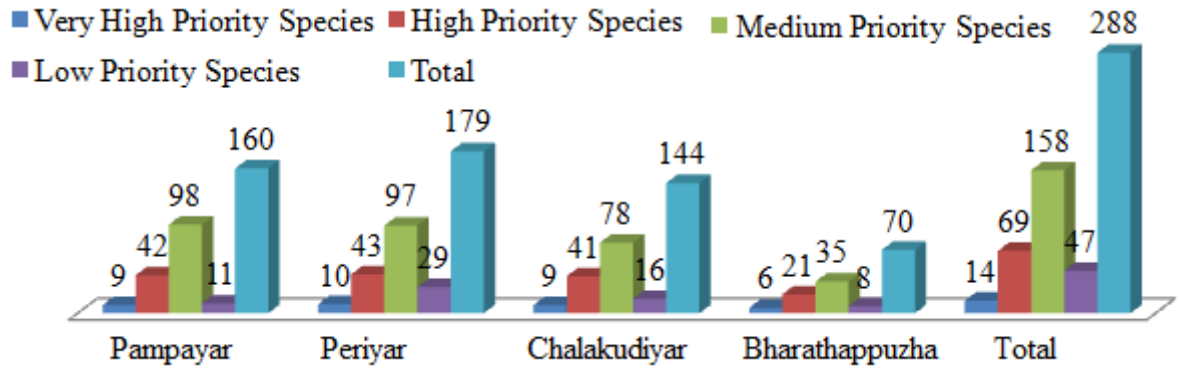

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Fig. 4.34
Prioritised List of species for River Bank Afforestation in four Rivers

Even though we have short listed the species for future afforestation programs, we may also use remaining species identified as having high conservation values for the afforestation programs in the respective Rivers. The species shall be selected based on its area od distribution and conservation values as mentioned in Annexure III.

4.5 IDENTIFICATION AND PRIORITIZATION OF AREAS FOR INTERVENTION

4.5.1 Criteria for Prioritization

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 listed by Sankaran et. al. (2013) and vi) Riparian lans use classes.. The prioritization criteria scores assigned to different parameters is given Table 4.18.

Table 4.18
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

Criteria/Parameters	Score
Vulnerable (VL)	3
Kerala (KL)	10
Southern Western Ghats (SWG)	8
Western Ghats (WG)	6
Peninsular India (PI)/India	4
Distribution of Invasive Species (Maximum Value 20)	
Invasive –A	20
Invasive –B	15
Invasive –C	8
Invasive –D	4
Riparian Land us e(Maximum Value 20)	
Barren/Built up	20
Vegetable cultivation	15
Trees (Mono crop)	10
Mixed Tree Crops	5
Natural Vegetation	0
Maximum Score	**100**

Based on the scores obtained the riparian areas were classified into four categories viz. Very high for first stage/immediate/short term intervention, High for second stage/ medium term intervention, Medium for long term intervention and in Low Priority areas not much intervention needed, but requires frequent monitoring.

Score > 75 - Very High Priority

Score 50- 75- High Priority

Score 15- 49- Medium Priority

Score < 15- Low Priority

4.5.2 Areas Prioritised for Intervention

The maps showing areas prioritised for intervention in four classes as per the criteria mentioned is given in plates 36 to 41. 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 (Fig. 4.35).

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. The details are reflected in Fig. 4.36.

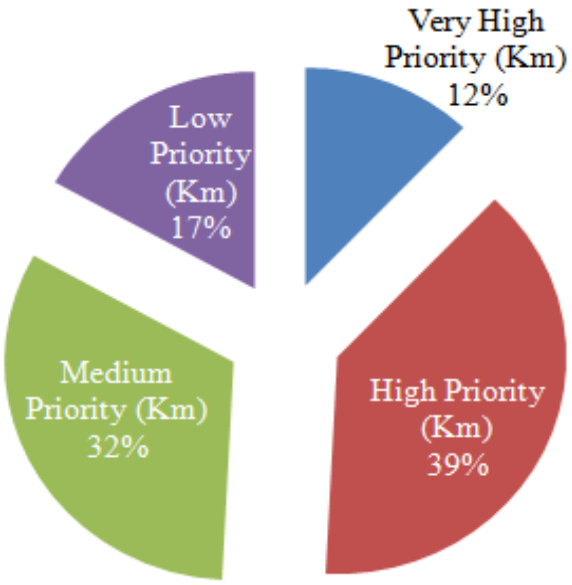

Fig. 4.36
Riparian area prioritised for intervention in Four Rivers

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 in the lowest is in Bharathapuzha (10%).

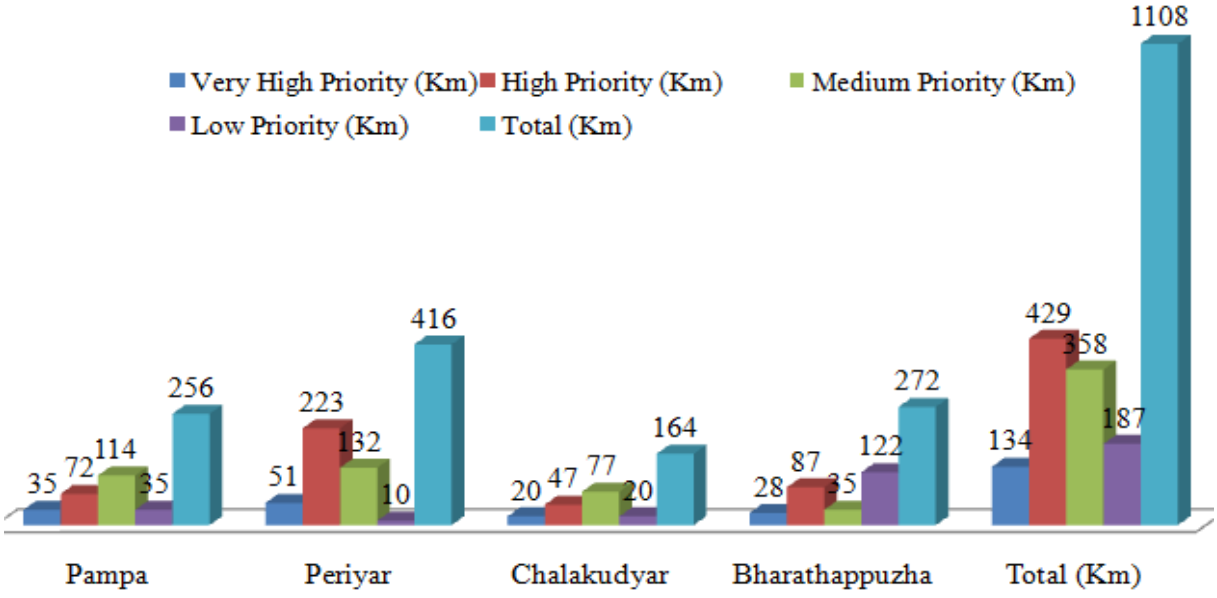

Fig. 4.36
Total distance of riparian area prioritised for intervention in four rivers

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).

The River wise details are discussed separately.

4.5.2.1 Pampayar

The maps showing the areas prioritised for intervention in Pampayar is given in plates 36 A to AM. The local body wise details of area prioritised for intervention at different stages is given in Table 4.19.

Table 4.19
Local body wise Riparian Areas Prioritised for Intervention in Pampayar (Distance-Km)

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
1	Kumily	1.0	0.0	**1.0**	1.6	0.0	**1.6**	6.3	0.0	**6.3**	0.0	0.0	**0.0**
2	Seethathode	1.0	2.0	**3.1**	0.0	1.9	**1.9**	0.0	3.5	**3.5**	0.0	0.0	**0.0**
3	Chittar	2.4	5.3	**7.6**	3.6	6.2	**9.8**	2.9	6.2	**9.1**	0.0	1.5	**1.5**
4	Erumely	1.5	0.0	**1.5**	2.5	0.0	**2.5**	0.4	0.0	**0.4**	0.0	0.0	**0.0**
5	Vechoochira	5.5	0.0	**5.5**	1.8	0.0	**1.8**	1.6	0.0	**1.6**	0.0	0.0	**0.0**
6	Naranammoozhi	0.0	1.1	**1.1**	0.0	2.3	**2.3**	0.0	6.5	**6.5**	0.0	0.0	**0.0**
7	Ranni-Perunnadu	0.0	0.4	**0.4**	0.0	0.6	**0.6**	0.0	3.8	**3.8**	0.0	0.0	**0.0**
8	Ranni-Pazhavangadi	3.7	0.0	**3.7**	0.3	0.0	**0.3**	3.4	0.0	**3.4**	0.0	0.0	**0.0**
9	Vadaserikkara	1.0	0.4	**1.4**	5.3	3.6	**9.0**	0.7	0.0	**0.7**	0.0	0.0	**0.0**
10	Ranni	0.0	0.4	**0.4**	0.0	6.8	**6.8**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
11	Ranni-Angadi	0.0	0.0	**0.0**	2.7	0.0	**2.7**	0.5	0.0	**0.5**	0.0	0.0	**0.0**
12	Ayiroor	0.0	0.0	**0.0**	5.9	0.0	**5.9**	2.2	0.0	**2.2**	0.0	0.0	**0.0**
13	Cherukole	0.0	5.0	**5.0**	0.0	1.4	**1.4**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
14	Kozhencherry	0.0	1.9	**1.9**	0.0	0.7	**0.7**	0.0	3.4	**3.4**	0.0	0.0	**0.0**
15	Thottapuzhassery	0.3	0.0	**0.3**	0.7	0.0	**0.7**	6.0	0.0	**6.0**	0.0	0.0	**0.0**
16	Mallappuzhassery	0.0	0.0	**0.0**	0.0	0.4	**0.4**	0.0	1.2	**1.2**	0.0	0.0	**0.0**
17	Aranmula	0.0	0.0	**0.0**	0.0	0.6	**0.6**	0.0	5.0	**5.0**	0.0	0.0	**0.0**
18	Koipram	0.0	0.0	**0.0**	0.9	0.0	**0.9**	3.3	0.0	**3.3**	0.0	0.0	**0.0**
19	Kadapra	0.1	0.5	**0.7**	2.6	2.3	**4.9**	6.6	1.1	**7.7**	0.0	0.0	**0.0**
20	Niranam	0.0	0.0	**0.0**	0.0	0.0	**0.0**	1.6	0.0	**1.6**	0.0	0.0	**0.0**
21	Chengannur Municipality	0.2	0.0	**0.2**	0.3	1.0	**1.3**	4.9	4.9	**9.8**	0.0	0.0	**0.0**
22	Pandanadu	0.0	0.1	**0.1**	2.7	1.4	**4.1**	2.3	5.0	**7.3**	0.0	0.0	**0.0**
23	Thiruvanvandoor	0.0	0.3	**0.3**	0.7	0.0	**0.7**	0.7	0.0	**0.7**	0.0	0.0	**0.0**
24	Mannar	0.0	0.4	**0.4**	0.0	1.7	**1.7**	0.0	2.3	**2.3**	0.0	0.0	**0.0**
25	Veeyapuram	0.0	0.0	**0.0**	0.0	2.0	**2.0**	1.3	2.7	**4.0**	0.0	0.0	**0.0**
26	Cheruthana	0.6	0.0	**0.6**	2.2	1.8	**4.0**	2.9	4.0	**6.9**	0.2	0.0	**0.2**

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
27	Thakazhi	0.0	0.0	**0.0**	2.1	0.8	**2.9**	4.2	3.0	**7.2**	1.7	4.9	**6.6**
28	Champakulam	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.4	0.0	**0.4**	0.5	0.0	**0.5**
29	Nedumudi	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.5	0.0	**0.5**	10.5	0.0	**10.5**
30	Kainakary	0.0	0.0	**0.0**	0.0	0.0	**0.0**	6.7	0.0	**6.7**	0.5	0.0	**0.5**
31	Ambalapuzha South	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	2.7	0.0	**2.7**
32	Ambalapuzha North	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	2.3	**2.3**
33	Punnapra South	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.4	**0.4**	0.0	3.1	**3.1**
34	Punnapra North	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	1.1	**1.1**	0.0	7.3	**7.3**
Total		**17**	**18**	**35**	**36**	**36**	**72**	**60**	**54**	**114**	**16**	**19**	**35**

River pampa is having 14% of area in very high priority for immediate intervention (Percentage wise highest of all rivers studied). There are 28% for second stage intervention, 44% for long term intervention and another 14 % requires not much intervention other than monitoring (Fig. 4.37).

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).

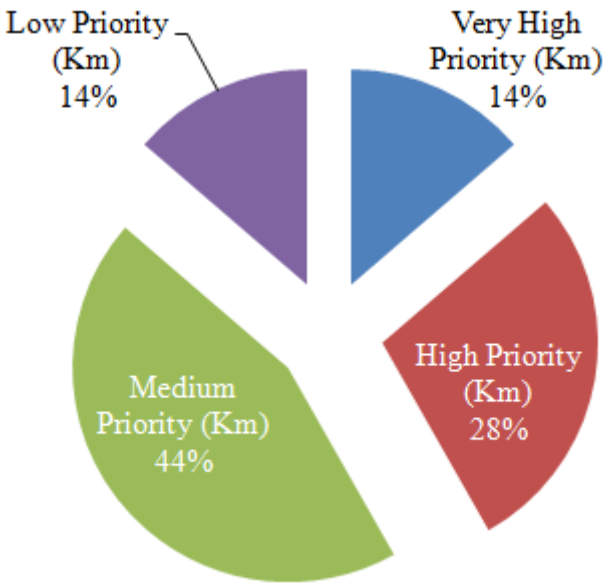

Fig. 4.37
Riparian area prioritised for intervention in Pampayar

26 local bodies require medium term intervention of which 7 local bodies are having more than 3 km distance of river bank in this category. They are: Chittar (9.8 km), Vadasserikkara

(9 km), Ranni (6.8 km), Ayiroor (5.9 km), Kadapra (4.9 km), Pandanad (4.1 km) and Cheruthana (4 km).

30 local bodies are there in the long term intervention category of which 17 local bodies are having more than 3 km distance of river bank in this category. The top five are: Chengannur Municipality (9.8 km), Chittar (9.1 km), Kadapra (7.7 km), Pandanad (7.3 km) and Thakazhi (7.2 km).

Only 10 local bodies are there in the low category which requires not much intervention but monitoring only. Out of this 4 local bodies are having more than 3 km distance of river bank in this category. They are: Nedumudi (10.5 km), Punnapra North (7.3 km), Thakazhi (6.86 km) and Punnapra South (3.1 km).

4.5.2.2 Periyar

The maps showing the areas prioritised for intervention in Periyar is given in plates 37 A to T. The local body wise details of area prioritised for intervention at different stages is given in Table 4.20.

Table 4.20
Local body wise Riparian Areas Prioritised for Intervention in Periyar (Distance-Km)

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
1	Kumily	2.2	0.0	**2.2**	10.6	0.0	**10.6**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
2	Vandiperiyar	0.0	0.0	**0.0**	0.0	5.6	**5.6**	0.0	2.8	**2.8**	0.0	0.0	**0.0**
3	Elappara	0.0	3.6	**3.6**	0.0	3.1	**3.1**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
4	Upputhara	0.0	0.0	**0.0**	0.0	5.2	**5.2**	0.0	6.3	**6.3**	0.0	0.0	**0.0**
5	Ayyappankovil	0.0	0.0	**0.0**	10.2	0.0	**10.2**	3.4	0.0	**3.4**	0.0	0.0	**0.0**
6	Vazhathoppu	0.3	0.3	**0.6**	2.7	1.9	**4.6**	0.0	0.0	**0.0**	0.9	0.9	**1.7**
7	Udumbannur	0.0	2.2	**2.2**	0.0	13.6	**13.6**	0.0	10.9	**10.9**	0.0	0.0	**0.0**
8	Vathikudy	8.9	0.0	**8.9**	1.8	0.0	**1.8**	1.8	0.0	**1.8**	0.0	0.0	**0.0**
9	Konnathadi	0.0	0.0	**0.0**	1.6	0.4	**2.0**	0.0	3.6	**3.6**	0.0	0.0	**0.0**
10	Vellathooval	0.0	0.0	**0.0**	0.0	0.0	**0.0**	3.6	0.0	**3.6**	0.0	0.0	**0.0**
11	Adimali	14.5	0.0	**14.5**	12.9	0.0	**12.9**	0.4	0.0	**0.4**	0.0	0.0	**0.0**
12	Karimannur	0.0	0.0	**0.0**	0.0	2.6	**2.6**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
13	Vannappuram	0.0	0.0	**0.0**	0.0	0.6	**0.6**	0.0	3.3	**3.3**	0.0	0.0	**0.0**
14	Kuttampuzha	2.8	0.0	**2.8**	24.1	13.3	**37.4**	13.2	9.4	**22.6**	0.0	0.0	**0.0**
15	Kavalangad	0.0	0.0	**0.0**	0.0	2.1	**2.1**	0.0	13.2	**13.2**	0.0	1.8	**1.8**

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
16	Keerampara	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	3.0	**3.0**	0.0	3.0	**3.0**
17	Ayyampuzha	0.0	0.0	**0.0**	11.8	0.0	**11.8**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
18	Pindimana	0.0	0.0	**0.0**	0.0	3.5	**3.5**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
19	Vengoor	0.0	0.0	**0.0**	0.0	9.0	**9.0**	0.0	3.6	**3.6**	0.0	0.0	**0.0**
20	Malayattur-Neeleswaram	3.9	0.0	**3.9**	5.3	0.0	**5.3**	1.1	0.0	**1.1**	0.0	0.0	**0.0**
21	Koovappady	0.0	0.9	**0.9**	0.0	5.7	**5.7**	0.0	5.8	**5.8**	0.0	0.0	**0.0**
22	Okkal	0.0	2.5	**2.5**	0.0	2.0	**2.0**	0.0	3.0	**3.0**	0.0	0.0	**0.0**
23	Kalady	1.1	0.0	**1.1**	2.3	0.0	**2.3**	0.9	0.0	**0.9**	0.0	0.0	**0.0**
24	Kanjoor	0.4	0.0	**0.4**	3.5	0.0	**3.5**	5.2	0.0	**5.2**	0.0	0.0	**0.0**
25	Perumbavoor (ML)*	0.0	0.8	**0.8**	0.0	0.0	**0.0**	0.0	0.6	**0.6**	0.0	0.0	**0.0**
26	Sreemoolanagaram	3.1	0.0	**3.1**	4.9	0.0	**4.9**	0.6	0.0	**0.6**	0.0	0.0	**0.0**
27	Vazhakkulam	0.0	2.4	**2.4**	0.0	2.5	**2.5**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
28	Keezhumad	0.0	0.9	**0.9**	0.0	4.8	**4.8**	0.0	0.3	**0.3**	0.0	0.0	**0.0**
29	Aluva Municipality	0.0	0.0	**0.0**	4.5	10.0	**14.5**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
30	Chengamanadu	0.0	0.0	**0.0**	5.5	0.0	**5.5**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
31	Nedumbassery	0.0	0.0	**0.0**	0.7	0.0	**0.7**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
32	Kunnukara	0.0	0.0	**0.0**	5.8	0.0	**5.8**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
33	Karumaloor	0.0	0.0	**0.0**	0.0	9.8	**9.8**	0.0	0.7	**0.7**	0.0	0.0	**0.0**
34	Chendhamangalam	0.0	0.0	**0.0**	0.0	0.4	**0.4**	0.0	3.6	**3.6**	0.0	0.0	**0.0**
35	Puthenvelikkara	0.0	0.0	**0.0**	2.5	1.1	**3.5**	7.1	2.1	**9.2**	0.0	0.0	**0.0**
36	Vadakkekara	0.0	0.0	**0.0**	0.0	0.4	**0.4**	0.0	2.3	**2.3**	0.0	0.6	**0.6**
37	Pallippuram	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	2.0	**2.0**
38	Kodungallur Municipality	0.0	0.0	**0.0**	1.2	0.0	**1.2**	4.1	0.0	**4.1**	0.0	0.0	**0.0**
39	Eriyad	0.0	0.0	**0.0**	0.0	0.0	**0.0**	3.2	0.0	**3.2**	0.6	0.0	**0.6**
40	Kadungalloor	0.0	0.0	**0.0**	5.1	0.0	**5.1**	3.6	0.0	**3.6**	0.0	0.0	**0.0**
41	Choornikara	0.0	0.0	**0.0**	0.0	2.1	**2.1**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
42	Eloor	0.0	0.0	**0.0**	0.0	6.4	**6.4**	0.0	3.5	**3.5**	0.0	0.0	**0.0**
43	Alangadu	0.0	0.0	**0.0**	0.0	0.0	**0.0**	2.9	0.0	**2.9**	0.0	0.0	**0.0**
44	Varappuzha	0.0	0.0	**0.0**	0.0	0.0	**0.0**	2.8	0.0	**2.8**	0.0	0.0	**0.0**
Total		**37**	**14**	**51**	**117**	**106**	**223**	**54**	**78**	**132**	**1.5**	**8.2**	**9.7**

Periyar is having 12% of its area studied in very high priority for immediate intervention, 54% for second stage intervention, 32% for long term intervention and only 2% area requires not much intervention other than monitoring (Fig. 4.38)

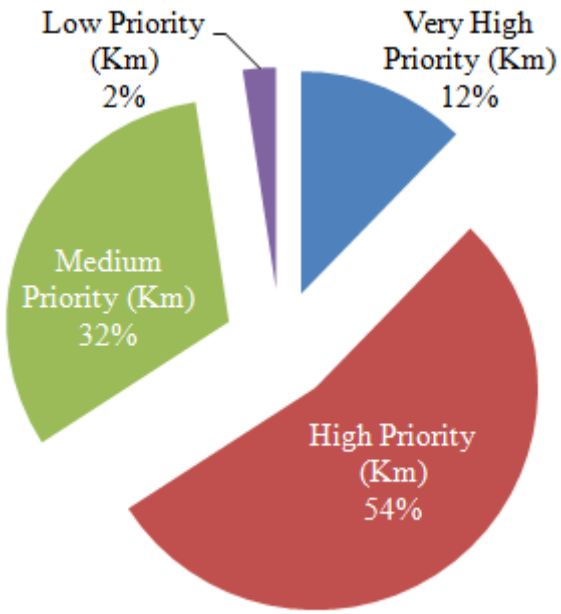

Fig. 4.38
Riparian area prioritised for intervention in Periyar

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).

37 local bodies require medium term intervention of which 24 local bodies are having more than 3 km distance of river bank in this category. The top five are: Kuttampuzha (37.4 km), Aluva Municipality (14.5 km), Udumbannur (13.6 km), Adimali (12.9 km) and Ayyampuzha (11.8 km).

31 local bodies are there in the long term intervention category of which 19 local bodies are having more than 3 km distance of river bank in this category. The top five are: Kuttampuzha (22.6 km), Kavalangad (13.2 km), Udumbannur (10.9 km), Puthenvelikkara (9.2 km) and Upputhara (6.3 km).

Only 6 local bodies are there in the low category which requires not much intervention but monitoring only. Out of this only one local body, Keerampara (30 Km) is having more than 3 km distance of river bank in this category.

4.5.2.3 Chalakudyar

The maps showing the areas prioritised for intervention in Pampayar is given in plates 38 A to O. The local body wise details of area prioritised for intervention at different stages is given in Table 4.21.

Table 4.21
Local body wise Riparian Areas Prioritised for Intervention in Chalakudyar (Distance-Km)

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
1	Athirappilly	9.7	8.3	18.0	18.8	7.6	26.4	6.8	0.2	7.1	0.0	0.0	0.0
2	Ayyampuzha	0.0	0.8	0.8	0.0	7.7	7.7	0.0	11.6	11.6	0.0	1.7	1.7
3	Manjapra	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0
4	Pariyarm	0.0	0.0	0.0	0.0	0.0	0.0	14.6	0.0	14.6	0.0	0.0	0.0
5	Karukutti	0.0	0.0	0.0	0.0	1.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0
6	Meloor	0.0	0.0	0.0	0.0	5.9	5.9	0.0	9.6	9.6	0.0	0.0	0.0
7	Chalakkudy	0.9	0.0	0.9	3.1	0.0	3.1	5.4	0.0	5.4	0.0	0.0	0.0
8	Mala	0.0	0.0	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
9	Kadukutty	0.0	0.0	0.0	0.1	0.0	0.1	4.9	9.0	13.9	0.0	0.0	0.0
10	Annamanada	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.2	5.5	0.0	3.3	3.3
11	Parakkadavu	0.0	0.0	0.0	1.0	0.0	1.0	3.3	3.5	6.8	0.3	3.4	3.7
12	Kuzhur	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	5.3	0.0	5.3
13	Puthenvelikkara	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.7	4.6	1.2	4.3	5.5
Total		**11**	**9**	**20**	**24**	**23**	**47**	**39**	**38**	**77**	**7**	**13**	**20**

Chalakudyar is having 12% of its area studied under very high priority for immediate intervention, 29% for second stage intervention, 47% for long term intervention and 12% area requires not much intervention other than monitoring (Fig. 4.39)

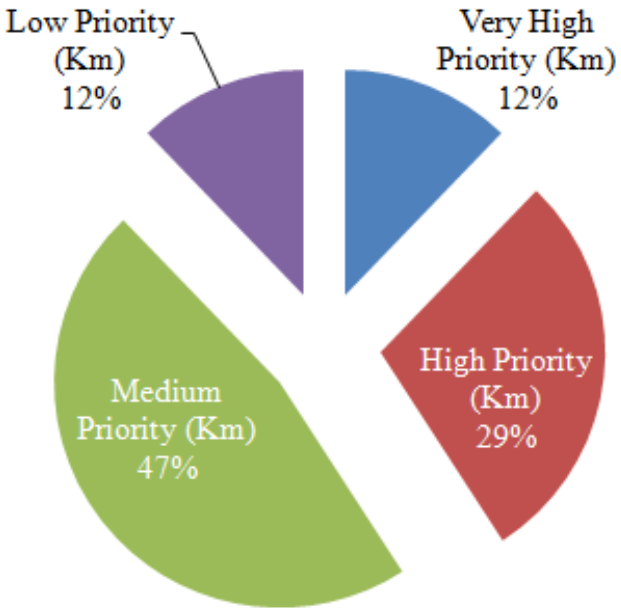

Fig. 4.39
Riparian area prioritised for intervention in Chalakudyar

Out of the 13 local bodies studied in Chalakudyar, only 3 are 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).

Nine local bodies require medium term intervention of which 4 local bodies are having more than 3 km distance of river bank in this category. They are: Athirappilly (26.4 km), Ayyampuzha (7.7 km), Meloor (5.9 km), and Chalakudy Municipality (3.1 km).

10 local bodies are there in the long term intervention category of which 9 are having more than 3 km distance of river bank in this category. The top five are: Kadukutty (13.9 km), Pariyaram (12.2 km), Ayyampuzha (11.6 km), Meloor (9.6 km) and Athirappilly (7.1 km).

Only 5 local bodies are there in the low category which requires not much intervention but monitoring only. Out of which 4 are having more than 3 km distance of river bank in this category. They are: Puthenvelikkara (5.5 km), Kuzhur (5.3 km), Parakkadavu (3.7 km), and Athirappilly (3.3 km).

4.5.2.4 Bharathappuzha

The maps showing the areas prioritised for intervention in Pampayar is given in plates 39 A to M (Thootha), 40 A to E (Kalpathi) and 41A to D (Gayathri). The local body wise details of area prioritised for intervention at different stages is given in Table 4.22.

Table 4.22
Local body wise Riparian Areas Prioritised for Intervention in Bharathapuzha (Distance-Km)

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
Kalpathi Tributary													
1	Puthussery	0.0	0.0	**0.0**	2.4	3.4	**5.7**	1.7	0.0	**1.7**	0.3	3.0	**3.2**
2	Marutha road	0.0	0.0	**0.0**	2.9	3.8	**6.7**	0.9	0.3	**1.2**	1.8	1.2	**3.0**
3	Palakkad Municipality	0.0	1.2	**1.2**	2.1	2.7	**4.8**	0.3	0.0	**0.3**	0.1	1.5	**1.7**
4	Malampuzha	0.0	0.0	**0.0**	0.6	0.0	**0.6**	0.0	0.0	**0.0**	1.5	0.0	**1.5**
5	Akathethara	0.0	0.0	**0.0**	0.7	0.0	**0.7**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
6	Puthuppariyaram	0.0	0.0	**0.0**	3.8	0.0	**3.8**	0.0	0.0	**0.0**	1.0	0.0	**1.0**
7	Pirayiri	0.0	0.0	**0.0**	0.0	4.1	**4.1**	0.0	0.0	**0.0**	0.0	0.5	**0.5**
8	Parli	1.0	0.5	**1.5**	2.5	2.1	**4.7**	0.6	0.0	**0.6**	0.5	2.0	**2.5**
Total		**1.0**	**1.6**	**2.7**	**15**	**16**	**31**	**3.5**	**0.3**	**3.8**	**5.2**	**8.2**	**13**
Gayathri Tributary													
1	Vadakkancherry	0.0	0.0	**0.0**	0.7	0.7	**1.5**	2.0	1.4	3.4	1.5	1.5	3.0

No.	Grama Panchayat	Very High			High			Medium			Low		
		RB	LB	Total	RB	LB	Total	RB	LB	Total	RB	LB	Total
2	Kannampra	0.0	0.0	**0.0**	0.0	1.6	**1.6**	0.0	1.1	**1.1**	0.0	1.9	**1.9**
3	Kavassery	0.0	0.0	**0.0**	2.1	0.0	**2.1**	4.8	0.0	**4.8**	2.5	0.0	**2.5**
4	Puthukkad	0.0	0.0	**0.0**	0.5	0.0	**0.5**	0.0	2.4	**2.4**	0.0	2.0	**2.0**
5	Pazhayannoor	0.0	0.0	**0.0**	0.0	1.4	**1.4**	0.0	3.7	**3.7**	0.0	3.2	**3.2**
6	Tharur	0.0	0.0	**0.0**	1.2	0.0	**1.2**	1.0	0.0	**1.0**	1.2	0.0	**1.2**
7	Thiruvillamala	0.0	0.0	**0.0**	3.0	0.0	**3.0**	4.0	0.0	**4.0**	3.1	0.0	**3.1**
8	Kondazhy	0.0	0.0	**0.0**	0.0	4.2	**4.2**	0.0	2.0	**2.0**	0.0	2.3	**2.3**
9	Ottappalam Municipality	0.0	0.0	**0.0**	1.0	0.0	**1.0**	0.0	1.0	**1.0**	0.8	0.0	**0.8**
Total		**0.0**	**0.0**	**0.0**	**8.5**	**7.9**	**16**	12	11	**23**	9	11	**20**
Thootha Tributary													
1	Kumaramputhur	3.6	0.0	**3.6**	2.4	0.0	**2.4**	0.5	0.9	**1.5**	8.3	4.8	**13.2**
2	Mannarkkad	0.0	5.8	**5.8**	0.0	0.0	**0.0**	0.0	0.6	**0.6**	0.0	3.4	**3.4**
3	Karimpuzha	1.5	0.0	**1.5**	6.1	0.0	**6.1**	2.6	0.0	**2.6**	2.6	3.9	**6.5**
4	Sreekrishnapuram	0.0	1.1	**1.1**	0.0	1.8	**1.8**	0.0	2.3	**2.3**	0.0	1.0	**1.0**
5	Vellinezhi	0.0	1.0	**1.0**	0.0	5.3	**5.3**	0.0	1.7	**1.7**	0.0	0.0	**0.0**
6	Thachanattukara	2.0	0.0	**2.0**	2.6	0.0	**2.6**	0.0	0.0	**0.0**	0.0	0.0	**0.0**
7	Aaliparambu	0.0	0.0	**0.0**	3.1	0.0	**3.1**	4.1	0.0	**4.1**	3.1	0.0	**3.1**
8	Cherplassery	0.0	4.2	**4.2**	0.0	1.3	**1.3**	0.0	0.3	**0.3**	0.0	3.4	**3.4**
9	Nellaya	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	1.4	**1.4**	0.0	2.4	**2.4**
10	Elamkulam	1.0	0.0	**1.0**	0.0	0.0	**0.0**	3.5	0.0	**3.5**	5.1	0.0	**5.1**
11	Kulukkallur	0.0	0.0	**0.0**	0.0	1.7	**1.7**	0.0	1.3	**1.3**	0.0	6.7	**6.7**
12	Pulamanthole	0.8	0.0	**0.8**	1.5	0.0	**1.5**	2.7	0.0	**2.7**	4.9	0.0	**4.9**
13	Vilayur	0.0	1.7	**1.7**	0.0	3.6	**3.6**	0.0	0.8	**0.8**	0.0	3.5	**3.5**
14	Moorkkanad	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	5.4	0.0	**5.4**
15	Thiruvegappura	0.0	1.5	**1.5**	0.0	6.4	**6.4**	0.0	1.4	**1.4**	0.0	1.4	**1.4**
16	Irumpliyam	1.0	0.0	**1.0**	1.7	0.0	**1.7**	1.9	0.0	**1.9**	8.3	0.0	**8.3**
17	Paruthur	0.0	0.0	**0.0**	0.0	1.6	**1.6**	0.0	0.0	**0.0**	0.0	1.3	**1.3**
18	Aanakkara	0.0	0.0	**0.0**	0.0	0.4	**0.4**	0.0	0.2	**0.2**	0.0	1.2	**1.2**
Total		**10**	**15**	**25**	**17**	**22**	**39**	**15**	**11**	**26**	**38**	**33**	**71**
Bharathappuzha Total		**31**	**35**	**66**	**21**	**29**	**49**	**31**	**23**	**53**	**52**	**52**	**104**

In Bharathappuzha, 10% of its area studied is in very high priority for immediate intervention, 32% for second stage intervention, 20% for long term intervention and 38% area requires not much intervention other than monitoring (Fig. 4.39). However, the 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%). In Gayathri tributary. Areas which does not need mauch intervention (low priority) is highest also in Thootha (44%) followed by Gayathri (33.7%) and Kalpathi (26.1%).

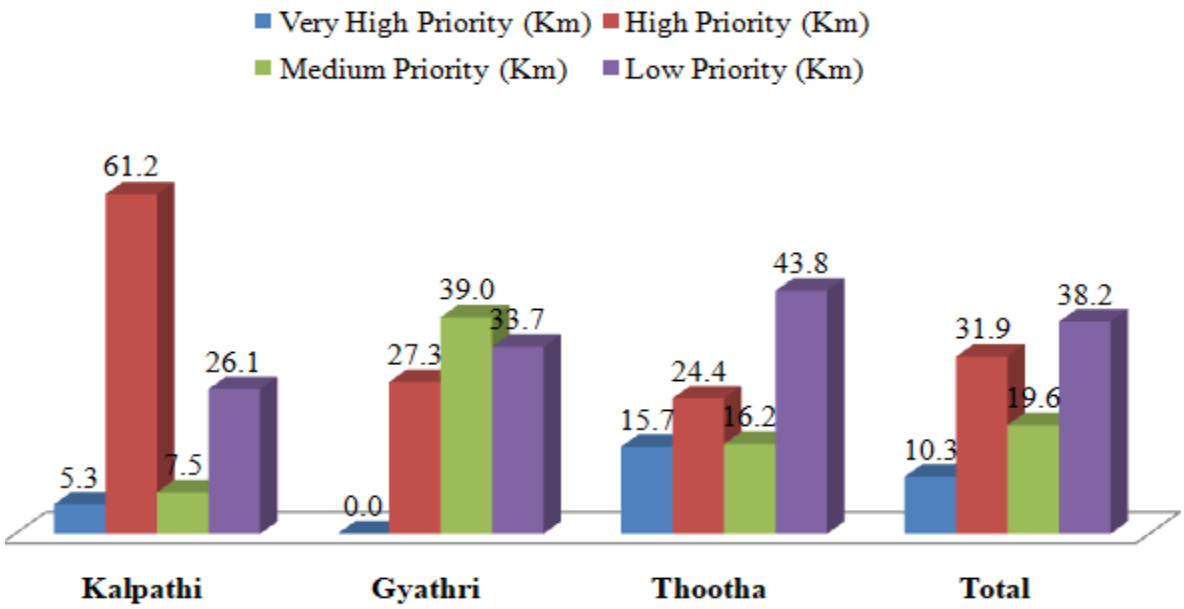

Fig. 4.39
Percentage of Riparian area prioritised for intervention in Bharathapuzha

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).

31 local bodies require medium term intervention of which 13 local bodies are having more than 3 km distance of river bank in this category. The top 5 are: Marutha Road (6.7 km) and Puthusseri (5.7 km) in Kalpathi tributary, Thiruvegappura (6.4 km), Karimpuzha (6.1 km) and Vellinezhi (5.3 km) in Thootha.

28 local bodies are there in the long term intervention category of which 6 are having more than 3 km distance of river bank in this category. They are: Kavassery (4.8 km), Thiruvillamala (4 km), Pazhayannur (3.7 km) and Vadakkanchery (3.4 km) in Gayathri and Aaliparampa (4.1 km) and Elamkulam (3.5 km) in Thootha.

There are 32 local bodies in the low category which requires not much intervention but monitoring only. Out of this 16 are having more than 3 km distance of river bank in this category. The top five in this category are: Kumaraputhur (13.2 km), Irumpliyam (8.3 km), Kulukkallur (6.7 km), Karimpuzha (6.5 km) and Elamkulam (5.4 km), all in Thootha tributary.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS OF THE STUDY

5.1.1 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%).
- 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 identified by Sankaran et.al. (2013).
- 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).
- 116 species are found in the riparian areas of all the four rivers, 180 seen in three rivers, 287 in two rivers and the rest 660 in any one rive 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.
- Floristic data of the four Rivers were analysed in detail separately

5.1.2 Species with High Conservation Value

- The plant other than the cultivated species which area 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 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 (Fig. 4.11).
- 40 species recorded from the study area are there in the Red List Version 2019-1. 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 found in the area 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).
- 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 importances like raw material for local livelihood activities, plants very much associated with the wild animals and fishes for its breeding, nesting and also s staple food and found to be very much useful in checking river bank erosion, stabilizing banks, and controlling floods etc. The diversity 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).

5.2.3 Impact of flood/landslide on the ecosystem

- In order to assess the impact on the ecosystem, the study has mapped the different vegetation types in the riparian in the study area of the four Rivers before flood/landslide using Google Earth maps and prepared a base map.
- The major land use classes identified on riparian areas aremixed 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 Periyar (30%), Pampa (71%) followed by Bharathapuzha (53%), Chalakudy (52%) and least in
- Natural vegetation is highest in Pampa (71%) 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 only 1%.Mixed vegetable crops on riparian zone are noticed in only in Periyar and Bharathappuzha (1% and 0.4% respectively).
- The high distribution of barren/built up areas 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 rejuanation of the river.
- The major physical impact of the flood and landslide in the riparian areas are erosion and deposition on the banks. It was mapped using filed data and the two layers were then merged in single map.
- 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. 63% of the eroded areas are under high erosion category.
- 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. About 54% of the eroded areas are under high erosion category.
- 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 category.
- Bharathapuzha is comparatively the least affected River by bank erosion. About 30% of the total distance under study and 30 out of the 35 local bodies studied were affected by River bank erosion. However, most of the erosions are in the medium and low category, only 11% of the eroded areas are under high erosion category.
- It is found that the banks with barren areas are highly eroded and with natural vegetation is less eroded. The best examples are 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.
- In the case od sand/mud deposition also, Periyar is the most highly affected with about 34% of the total distance and 33 out of the 44 local bodies were affected by sand/mud

deposition at various scales. About 31% of the mud/sand deposition is under high category.

- Pampayar is also highly affected by mud/sand deposition with 74% of the total distance and 27 out of the 34 local bodies were affected by sand/mud deposition. About 17% of the mud/sand deposition is under high category.
- 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.
- 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.
- Another major impact on the riparian ecosystem due to flood is deposition of inorganic wastes, mainly plastics on the trees and other vegetation causing damage to the species and ecosystem. The study has not attempted a detailed analysis of the issue due to shortage of time and funding.

5.2.4 Impact of flood/landslide on the Riparian Flora

- The study has revealed that 604 species are affected by flood/landslide in various rivers.
- However, it is found that all the species which has damaged in one place is found in other areas of the same River and 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 we were not able to see it there 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.
- It is 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.
- About 60% of the plants f 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 were even spread to more locations.
- There are 56 species which has dried after this. Most of them are cultivated species (43 species). Cultivated species in the riparian areas were damaged mainly due to highly turbid water retained in the area for three to four days and the soil condition is changed.
- Plants belongs to 189 species has uprooted and washed out during the flood. All these plants are growing close to the bank and were happened mainly due to bank erosion. In many instances, large trees uprooted in landslide in the up streams coming in high velocity was collided with the trees
- 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 highest 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 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 n 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 n 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)

5.2.5 Spread of Invasive species

- One of major impact of the August 2018 flood/landslide in Kerala to the riparian ecosystem/vegetation is the spread of many invasive plants listed by a recent study by Sankaran et.al. (2013) published by the Kerala State Biodiversity Board.
- 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 the 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.

5.2.6 Potential species Identified for River Bank afforestation

- The study has developed a criteria for identification of species potential for future River bank afforestation programs.

- One of the objectives of the present investigation is to identify potential riparian species for afforestation activities in the riparian ecosystem in Kerala. 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).

5.2.7 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 listed by Sankaran et. al.(2013) and vi) Riparian lans 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 in the lowest is in Bharathapuzha (10%).
- 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).

- The Bharathappuzha 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%). In Gayathri tributary. Areas which does not need mauch intervention (low priority) is highest also in Thootha (44%) followed by Gayathri (33.7%) and Kalpathi (26.1%).

5.2 DEVELOPING RIVER MANAGEMENT ACTION PLAN AND IMPLEMENTATION

5.2.1 Framework for Developing River Management Action Plan

The planet's climate is changing causing disatsters and extreme events all over the world. We had also severe experiences during the last August has casuing damages to the people and ecosystem. It has also resulted in severe water shortages in the Rivers, wells etc. bringing hardship to residents and other living organism. Scientists are working for new approaches for dealing the issues.

It is a proven fact that the Rivers in Kerala are facing tough times during the past few years. Climate change is also contributing in magnifying the pressures on river ecosystems brought on by urbanization, invasive species and pollution. As the crisis worsens, we need to change how we understand and manage Rivers to safeguard the services they provide to humanity and the entire planet. All the above facts pin point the need for new strategies for river management to maintain water supplies and avoid big crashes in populations of aquatic life. The riparianares play an important role in River health and the present study mainly attempted to assess the impact of the flood/landslide on the riparian flora and the causes of the impact.

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 occurred in that area. Based on the case studies conducted in the four major rivers the recommendations for conservation and management is recommended.

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 or nourishment program should take into account the basin scale processes and basin-wide responses of the river system for effective management. Even though rivers have a self-healing ability to the anthropogenic interventions, this ability is limited and if exceeded, the resultant damage would be irreversible. However, the study found 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.

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. For checking the soil erosion in the river basin areas, many activities are being undertaken by various departments like soil conservation, irrigation department, western ghat development cell of planning board etc. The local bodies are also planning to take up many activities related to waste management with the help of Suchithwa Mission. However, integration of these activities is lacking and is being undertaken piece meal without a proper management plan.

Given cognizance to the importance of holistic study, integrated management practices, and sustenance of environmental flow of river systems for nourishment of river basin ecosystems, there are a number of international efforts in terms of the Stockholm conference on the Human Environment (1972), United Nations conference on Environment and Development (1992), International Geosphere -Biosphere Program, International Human Dimension Program, and more recently, the EU water framework directive, and flood directive. There are many other programs that provide a comprehensive guideline for environmental management of river basins.

The recent thinking all over the world is an ecosystem based approach for river basin management which is based on certain findings that:

- River basins are far more than the waters within their banks
- They are living systems that include groundwater, springs, wetlands, ponds, streams, lakes and estuaries

- These systems reflect the natural characteristics of their basins and the effects of all human activities within them
- The biophysical environment such as physiography, vegetation, soil and water, systematized within a river basin, has a direct bearing on man
- Thus river basins, undoubtedly serve as basic units for the study of land and water management.

The 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 and is given detail inin Table 5.1.

5.2.2 . Methods and Technologies for Intervention

5.2.2.1 Awareness Creation and Capacity Building of Stakeholders

The major objective of all the river conservation programmes is to rehabilitate, restore and manage the River ecosystem in order to provide improved livelihoods, especially for the poor, enhanced biodiversity, and a sustainable supply of water for domestic and industrial, recreational and emergency uses. While catchment management institutions across the world have largely embraced the inherent biophysical and social message of sustainability, translating this ideal into treatment policy and practice is an ongoing challenge. The need for such cross-dimensional understanding is reinforced by the wide range of motivations (conservation, social, educational, etc.) for volunteer involvement in catchment treatment. To evolve a better management practice, such involvement is crucial, and the most inclusive and engaging outline will be one that openly recognises and balances this range of priorities and motivations

Table 5.1
Framework for River Basin Management Action 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

Activity	Sub Activity	Institutional Responsibility	Departmental Support	Technical Support	Duration	Remarks
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	

Activity	Sub Activity	Institutional Responsibility	Departmental Support	Technical Support	Duration	Remarks
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	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	

Activity	Sub Activity	Institutional Responsibility	Departmental Support	Technical Support	Duration	Remarks
	• Removal of blocks in the streams and ensuring free flow in the streams					
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 river banks 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 management action plan for each river The River Management 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	-Do-	LSG Dept., Haritha Keralam Mission	EMC Kerala ANERT Dept. Of Archaeology, JNTBGRI,	Within 3 years on initiation of the program – Shall be taken up Parallel	

Activity	Sub Activity	Institutional Responsibility	Departmental Support	Technical Support	Duration	Remarks
	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			KFRI Fisheries Department, Agri. Dept., Medicinal Plant Board, KITTS etc.		
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 Assessment	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*

Conflict is also form an inescapable reality in river basin management. This is not a negative fact, since conflict is a catalyst for negotiation that brings participants to a platform upon which needs can be recognised as overlapping. However, in order to reap these benefits, the stakeholders have to be able to articulate their needs confidently and the practitioner needs to be supportive, neutral and open. Conflict is resolved through an inclusive process of collective action and negotiation. Through the collective action and the resolution of conflicts, people recognize their interdependence and their differences and learn to deal with them constructively. The capacity building activities shall be processes of social learning which determine the options that are taken into consideration for various activities in the River Basin.

The awareness and capacity level of different authorities, experts, interest groups and the public has to be improved for managing the river basin in an effective manner. The different stakeholder groups also need to learn and increase their awareness about their biophysical environment and about the complexity of social interactions. 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. Monitoring and evaluation also have the power to integrate river science and management, by bringing together geomorphologists, ecologists, hydrologists, geochemists, social scientists, and economists etc. to track river health and rehabilitation success and feed that into adaptive management structures.

The present study suggests the following programmes for awareness creation, capacity building and proper monitoring:

- Ensuring more accessible information sharing mechanism and facilities for river monitoring by establishing an Environmental Knowledge Hubs (EKH) with emphasis to river management and monitoring, this will cover almost all areas related to environment.
- Providing onsite training to trainers and officials
- Allowing stakeholders to participate in policy decision making processes on determining the level of resource extraction and setting environmental objectives.

- Encouraging various groups present in and around the local body, like doctors, engineers, scientists, academicians, farmers, and labourers etc., to come together and share their experiences in order to provide a coherent, less *ad hoc* body of knowledge.

The Environmental Knowledge Hubs to disseminate the message of conservation and management of river basin has to be initiated in a convenient location. This is a place for peoples from various stakeholder groups to interact, gather and exchange knowledge and suggests development activities in the local bodies considering all environmental factors. The activities suggested for the EKH are:

- Constructing a small environment friendly building to function the office, exhibition hall, training hall etc. The land for this has to be provided by the local body, preferably in the office premises (for better monitoring and management).
- 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

The EKH shall have a small office room, reading room cum exhibition hall (with permanent exhibition materials of local environment), training hall and toilets

5.2.2.2 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. However, a comprehensive CAT plan should also include the social dimensions associated directly or indirectly with the catchment. A well designed CAT plan should not only control the sedimentation of reservoir but should also provide a life support system to the local population through their active involvement. 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 following interim measures are recommended in the highly affected areas:

- The existing natural vegetation both in good and degrading state should be preserved and further degradation and fragmentation should not be allowed.
- Clearing of degraded forest for plantation development should be strictly controlled and intervention to 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 (Coconut, plantain etc.), 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.
- Critical slope areas shall be carefully treated and excluded while erecting land management structures to avoid slope failures.
- 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.



Base trenching **Mulching** **Cover crops**

Edakayyalas **Gully Plugging with Local material** **Contour Trenching**

- Contour trenchingchecking the velocity of runoff in the ridge area of any watershed. A contour trench is a trench dug along a contour line. Digging a trench along such a line increases the chances of containing run off for a longer period of time within the trench. It is also true that if trenches were not followed a contour, it will increase the possibility of soil erosion because there would be a rise in the velocity of runoff following an increase in the slope of the land.
- 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. Rain water harvesting is a process of collecting and storing water from an area that has been treated to increase precipitation run off. A ‘water harvesting system’ is described as the complete facility for collecting and storing precipitation run off. Traditional water harvesting system exists all over India but after serving the nation for several millennia they are dying a slow death. The Government of Kerala has taken the initiative to turn the rain water harvesting and water conservation into a mass movement in the state. The movement undertook campaign and measures for rainwater harvesting, protection of the environment and conservation of water bodies. The Government has also taken initiative to organize conventions to create awareness about the importance of water, rain water harvesting and environment among the people. The scheme is mainly promoting developing permanent Ferro-cement tanks for direct use of

collected water Rain water harvest pits for ground water recharge is practiced recently. However, there is no scientific approach for site selection and taking pits. The activity is undertaking mainly utilizing the Mahatma Gandhi Rural Employment Guarantee Scheme (MGNREGS). Based on the experience found in the practice followed now, the study suggests the following to make water harvest pits; The State has also initiated an open well recharge program called "*Mazhapolima"* in Thrissur district in 2009 implemented by the local bodies and done recharging a considerable number of well in the district. It was a very simple procedure to harvest rainwater, channel the harvested rainwater either directly to the open well (after passing through a sand and gravel filter) or put it into recharge pits constructed next to an open well. Basically it is the direct opposite of a pumping well. A recharge well pushes back surface water into the groundwater system. Usually, a recharge well is one metre in diameter and 2-4 metres deep, lined with concrete rings having perforations. These perforations let water seep from the sides. The rings line the recharge well from bottom to top with a steel or concrete ring closing it. Rainwater that gushes down terrace drains, and surface water flowing in storm water drains, can be filtered, de-silted and recharged in open wells. Complemented by an aquifer – an underground layer of water-bearing permeable rock or unconsolidated material such as sand, gravel, or silt – a recharge well helps increase the groundwater table.

5.2.2.3 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. A survey conducted by the fisheries department in 2000 and published 2002 (Pan fish book) has basic data on the ponds of Kerala. However, it is found that most of the ponds are now used for dumping waste.

The irrigation department has rejuvenated many ponds but due to unscientific practices like constructing concrete walls, the situation is worse in these ponds.

The study recommends the following in this regard.

- Conduct local body ward level surveys with people participation for ascertaining the present status of all ponds.
- Rejuvenate one pond in each ward with earthern bunds and vegetation as a model. Gabion shall be tried steep walls.
- Identify areas for new ponds through scientific methods using the TIN and DEM map etc. and develop ponds in an Ecofriendly way.
- Make use of the financial support from various Central/State Government departments including Kerala State Biodiversity Board for rejuvenating the ponds.

5.2.2.4 Checking Drainage Obstructions and Ensuring Free Flow in the Streams

A study by CED (2018) has mapped the obstructions in drainages in Vamanapuram River Basin and results are very much shocking. Most of the streams are now blocked by construction of buildings, roads etc. These areas shall be identified by using drianage maps of the basin based on which, concentrated efforts are to be undertaken to remove the blocks by people participation.

5.2.2.5 Addressing River Water Pollution Issues

Soil and water pollution comprises the pollution of soil and water with materials, both organic like solid and liquid waste from households and commercial establishments, fecal contamination through open defecation etc. and inorganic, mainly chemicals through agriculture runoff waters, industrial waste materials etc. The toxic chemicals leach into groundwater, or if contaminated runoff reaches streams, lakes, or oceans. Soil pollution also naturally contributes to air pollution by releasing volatile compounds into the atmosphere.

The various measures suggested for pollution management is discussed here.

Cleaning of water bodies: It is found that most of the ponds and other water bodies associated with our rivers are dumped with solid waste mainly plastic and other inorganic and inorganic substances. 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. In solid waste management programme expenditure can be brought down if it is implemented at the micro level. For example, 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. In both the

cases the expenditure can be reduced to such an extent that it can be shared by the community. As for market wastes and waste from other sources money for meeting capital expenditure has to be raised in advance as the cost involved will be high. Municipal Solid Waste (Handling and Management) Rules, 2000 provide a framework encompassing collection, transportation, treatment and disposal of municipal solid waste. These Rules are complemented by the existing Bio-medical Waste Rules of 1998 and Hazardous Waste Rules of 1989 respectively, whereby disposal of these wastes along with usual urban municipal waste is prohibited. Recently a more comprehensive legislation incorporating changed deadlines is issued by the Ministry, SWM Rules 2016. The Solid Waste Management (SWM) Rules, 2016 was published by the Ministry of Environment, Forests and Climate Change in supersession of the Municipal Solid Waste (Management and Handling) Rules, 2000. These rules are applicable to every local body and stipulate that all municipal authorities to scientifically manage the solid waste generated in their respective jurisdictions. Various biodiversity friendly are technologies like compost pits, pot compost, Pipe Composting, vermi composting etc. are now widely used in various parts of our state for processing of the biodegradable waste treatment.

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 are many centralized composting technologies practiced all over India, of which windrow composting is the most common technology implemented in most of the ULBs in

the country. Other technologies include Refuse Derived Fuel (RDF), Incineration, Pyrolysis or Waste Gasification, Sanitary engineered land filling etc. Thus there is no shortage for technologies, proper implementation is only lacking. 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. T Wastewater can be classified according to the source of generation. The constituents of waste water also vary depending on the source of generation. The term "domestic wastewater "refers to flows discharged principally from residential sources generated by such activities as food preparation, laundry, cleaning and personal hygiene. "Industrial/commercial wastewater" is the flow generated and discharged from various types of manufacturing and commercial activities. "Agricultural wastewater" is water carrying waste material from agricultural activities (manure, plant stalks, hulls and leaves, pesticides etc).

This has another dimension also. The fresh water available in nature gets depleted day by day as change in climatic condition and human intervention such as deforestation. Even though this situation persists, it has been a challenging task for developing countries to provide safe and sufficient drinking water and proper sewerage systems in urban areas. 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.

Though industrial effluents also are dangerous, there are rules governing their management and the industries concerned are bound to take care of management and safe disposal of the effluents. If the Local Governments and other law enforcing agencies are watchful and vigilant, scientific disposal of industrial effluents can be made under control .Agricultural runoff will be much less in cities and may not be a major problem. Storm water is a natural

phenomenon and proper drainage system will be sufficient to manage the storm water. Waste water can be recycled/reused as a source of water for a multitude of water use such as agriculture, aquifer recharge, aquaculture, fire fighting, flushing of toilets, snow melting, industrial cooling, parks and golf course watering, formation of wetlands for wildlife habitats, recreational impoundments, and essentially for several other non-potable requirements (Mara and Cairncross 1989). Potential reuses of waste water depend on the hydraulic and biochemical characteristics of waste water, which determine the methods and degree of treatment required. The wastewater contains a broad spectrum of contaminants depending upon the type of use.

Grey water is a potential substitute for freshwater for a variety of uses, both domestic and industrial. Once the wasted grey water is captured and reused, the demand for potable water can be substantially reduced. Also the effort and money spent on wastewater management could be considerably reduced. Hence, Wastewater management strategy should essentially focus on grey water reuse in view of its latent capability to reduce the volume of wastewater to be treated with expensive treatment methods. There are many technologies available for treating the waste water which include Soakage Pits, The 4-Barrel System, The Confined Trench (CT) system, Septic Tank, Waste Stabilization Ponds, Constructed Wetland Treatment System etc.

Animal Slaughtering Wastes: The animal slaughter wastes one of the major organic wastes encountered in many Rivers in the State. None of the local bodies in Kerala is having a proper slaughter house. The management and maintenance of the slaughter houses generally comes

under the responsibility of the local bodies. There are also slaughter houses run by private agencies like the one run by Mosque committee in Taliparamba. Also there are many illegal slaughtering areas in many of the urban and Panchayats areas in the state. Effective waste management can reduce environmental problems associated with slaughter house. The strategy followed is to reduce waste by segregating resources from different types of wastes generated in the slaughter houses. Solid waste is the main waste product from a slaughter house. Solid waste from slaughter house can be divided into two main groups, namely edible & inedible. Organs such as brain, liver, heart are the examples of edible by-products. Hooves, horns, hair, gall bladder, ears, skin, bones etc. are the inedible by-products. The components left unrecovered forms are the solid wastes. In a modern slaughter house most of the solid wastes can be recovered as by-products. Success of material recovery depends on how slaughtering is done and how the facilities are provided in the slaughter house.

It may not be feasible to establish modern slaughter houses in each local body. Two options are suggested:

1. Establish a common slaughter house with necessary facility in a suitable location which can be utilised by two or more local bodies. Identification of suitable location considering the ease to transport animals and carcass is an important factor.
2. 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

5.2.2.6 Riparian Area Management

The major issues in Riparian areas identified by the study are:

- River Bank Slumping/Erosion
- High Deposition of sand and mud on the banks,
- Loss of vegetation including plants with high conservation values and
- 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. Bank scour is the direct removal of bank materials by the physical action of flowing water and is often dominant in smaller streams and the upper reaches of larger streams and rivers. 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 are examples of management practices 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. The erosion will result the loss of land, or property and endanger people who lives near the river. The objective of riverbank protection is to avoid bank erosion, which is caused by water current. The major effect of the erosion is collapse of riverbank, causing movement of river channel. The movement is both in vertical and horizontal direction, arise meandering, braiding, or move and changing its river path.

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. River side vegetation is an essential part of life for rivers and streams. They are also source of nutrients for the diverse species living in the river ecosystem and help to improve the water quality in the river/streams. 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. One way we can help preserve river health is by giving streams and rivers a chance to preserve themselves when appropriate, without human interference. Removing trees and shrubs from a river or stream should only be performed if it poses an imminent threat to human health, human safety, river integrity or public infrastructure.

River bank erosion is one of the predominant problems in the entire river systems in Kerala. The erosion will result the loss of land, or property and endanger people who lives near the river. The objective of riverbank protection is to avoid bank erosion, which is caused by water current. The major effect of the erosion is collapse of riverbank, causing movement of river channel. The movement is both in vertical and horizontal direction, arise meandering, braiding, or move and changing its river path. The present bank erosion control structures and programmes are not only very expensive but also are not compatible with environmental and aesthetic concept. The structures made from masonry or concrete disagree with the spirit and soul of eco-hydraulic, because, riverbank stability has an influence on channel form, vegetation growth and habitat for bank-living species. Eco-hydraulics is to solve the river problem with environment and ecology approach. Bank protection measures, which are matching with the spirit and soul of eco-hydraulics, must use locally available, cost effective,

natural materials and can provide habitat for river biodiversity. The river bank protection is not only intended for avoiding bank slumping but also to reduce leaching of nutrients and ensure water quality.

Some river bank protection method, other than the conventional masonry and concrete designs, are using gabions and vegetative protection.

Gabions are cylinders that are filled with earth or stones, which are used in building structures such as dams or dikes and are now used throughout the world for bed protection, bank stabilization, retaining walls, and numerous other purposes. Gabions come in three basic forms, the gabion basket, gabion mattress, and sack gabion. All three types consist of wire mesh baskets filled with cobble or small boulder material. The fill normally consists of rock material but other materials such as bricks have been used to fill the baskets. The baskets are used to maintain stability and to protect stream banks and beds. The difference between a gabion basket and a gabion mattress is the thickness and the aerial extent of the basket. A sack gabion is, as the name implies, a mesh sack that is filled with rock material. The benefit of gabions is that they can be filled with rocks that would individually be too small to withstand the erosive forces of the stream. The gabion mattress is shallower (0.5 to 1.5 ft) than the basket and is designed to protect the bed or banks of a stream against erosion. Gabion baskets are normally much thicker (about 1.5 to 3 ft) and cover a much smaller area. They are used to protect banks where mattresses are not adequate or are used to stabilize slopes, construct drop structures, pipe outlet structures, or nearly any other application where soil must be protected from the erosive forces of water.

Gabion Baskets

The rocks contained within the gabions provide substrates for a wide variety of aquatic organisms. Organisms that have adapted to living on and within the rocks have an excellent home, but vegetation may be difficult to establish unless the voids in the rocks contained within the baskets are filled with soil. If large woody vegetation is allowed to grow in the gabions, there is a risk that the baskets will break when the large woody vegetation is uprooted or as the root and trunk systems grow. Thus, it is normally not acceptable to allow large woody vegetation to grow in the baskets. The possibility of damage must be weighed

against the desirability of vegetation on the area protected by gabions and the stability of the large woody vegetation. If large woody vegetation is kept out of the baskets, grasses and other desirable vegetation types may be established and provide a more aesthetic and ecologically desirable project than gabions alone.

Gabions are suited to a variety of silt conditions. They can be used in perennial or ephemeral streams, and installation can occur in dry or wet conditions with the proper equipment. The main concern is the delivery and handling of the baskets and rock fill. If wet conditions exist for long periods of time in the area surrounding the site, the delivery of rock materials may be impossible or extremely problematic.

Gabion Protection of River: Before and after Protection

The most important consideration for the installation of gabions is the stability of the stream. If the stream is undergoing rapid changes in base elevation (down- cutting or deposition) or extreme lateral movement, plans should be made to correct the larger problems that are contributing to the local problem. If the larger problems are not addressed, local protection measures may be overwhelmed or flanked.

The aesthetics of gabions are not as desirable as some other types of protective measures such as re-vegetation, but where the damages and dangers associated with failures is high, or where serious erosion problems exist that cannot be controlled with other methods, gabions are a viable alternative.

Vegetative Protection

The use of vegetation as bank protection can be a less expensive measure. The present study has identified and prioritised en 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.

Bank erosion is noticed in many areas under study. Any strategy for checking erosion should consider this basic fact also. 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 and is discussed in detail in the chapter 4. The removal of this material requires proper scientific studies by experts in this area.

Loss of vegetation including plants with high conservation values: The issue of loss of vegetation including plants with high conservation values shall be compensated by undertaking planned riparian area afforestation programs using the locally available species identified and prioritised during the study.

Spread of Invasive species

Natural lands are not fully protected unless they also are managed for the features that first motivated preservation. Invasive species can change community structure, composition, and ecosystem processes on these lands in ways that may not be anticipated or desirable. Careful management can minimize these negative impacts. Invasive species are problematic as they can alter: i) nutrient cycling, ii) local hydrology, iii) fire regimes, iv) geomorphological processes (such as dune formation or stream profile), v) species and structural diversity, vi) available wildlife resources, and vii) prevent recruitment of native species due to competition for light, nutrients, and/or moisture.

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. This is needed to prevent the further spread of the species to other areas. The local bodies and BMCs can easily locate the areas identified in the study area using the map and control measures shall be undertaken using scientific methods.

Managing invasive species in urban landscapes has been at the forefront for the past few decades [65] yet remains a challenge given the interconnected role between government agencies charged with their management and private citizens who live in these area

There are four major control measures generally accepted for controlling invasive species are i) mechanical removal, ii) eradication of weeds using chemical, iii) biological control and iv) cultural techniques. (**https://conservationtools.org/guides/31-invasive-species-management-program**).

Mechanical methods are used extensively by staff and volunteers; they include hand pulling, weed wrench, cutting (high and low, in the case of vines), mowing, digging, bush hogging, prescribed burning, brush cutting and weed whipping and pulling with a tractor and chain or Brush Brute. These methods are effective if repeated frequently during a growing season to exhaust a plant's root reserves, or if used in combination with other techniques.

Chemical methods involve the use of herbicides. The decision to use chemical controls is a carefully considered one. The exclusive use of herbicides alone is not likely to be an effective long-term solution for controlling invasive species. Difficulties include controlling only target plants at the correct time during their life cycle, and the potential health risks to workers and the environment. Herbicides need to be applied only by trained and licensed personnel. In combination with physical methods of reducing the above-ground portion of a plant, herbicides may limit re-sprouting or effectively control plants when used in combination with other techniques. Typically herbicides are used in small quantities for a stump application immediately after an invasive is cut back, or they are used to control re-sprouts some time after the cutting. The environmental damage from invasive plants is considered to be greater than the risk associated with the use of non-persistent herbicides.

Biological control involves the introduction of species-specific predators from a plant's native habitat, and remains the domain of universities and government agencies. The risks associated with species introduction are high and only well funded and thoughtfully researched programs are effective.

Cultural control loosely describes changes to the structure or nutrient availability of a site to create conditions that do not favor invasive plants. This form of control includes:

- minimizing the edge habitats that are prone to invasion,
- amending soil to tie up excess nutrients,
- preventing access to control other invasive plants,
- replanting with a diversity of desirable species so that they can shade out invasive species.

Implementation of an invasive species management plan requires a long-term commitment to ongoing stewardship. 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. Assessment and interpretation of the scale and type of work required are key factors in ensuring a successful species management plan.

Prioritizing which species to control is an important consideration; there are never sufficient resources to manage them all and there will always be external sources of weeds—so it is important to determine which species are interfering most with your goals for the land. Ongoing funding for long-term maintenance may be limited, so prioritization is significant in the planning process.

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 which has been done for invasive species in Kerala by Sankaran et.al (2013).

5.2.3 Role of Local Bodies/BMCs

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. The local bodies in the State are also want to take up the case very seriously and looking for scientific technological support.

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 use of science in many plans is therefore inadequate. As a result, there is reliance on community preferences without adequate assessment of their scientific or economic realism. A shift in management practice is occurring all over now. This requires detailed investigation based on local condition rather than importation and misapplication of river rehabilitation techniques and processes from abroad. A shift in community and manager attitude towards river management and the process of implementation in the community is also needed.

The 73rd and 74th amendments to the Indian Constitution, envisages local bodies as the third tier of government along with the Central and State governments. This has been successfully implemented in the state of Kerala. 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.

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PROJECT TEAM