RIPARIAN FOREST COMPOSITION, CLASSIFICATION AND MAPPING IN RELATION TO BIOCLIMATE IN THE ANAMALAI LANDSCAPE UNIT, WESTERN GHATS

Thesis submitted to the
University of Calicut in partial fulfilment of the
requirements for the award of the degree of

DOCTOR OF PHILOSOPHY IN
BOTANY

By

POOJA SURESH

Under the guidance of

Dr. AMITHA BACHAN K. H.

RESEARCH DEPARTMENT OF BOTANY
MES ASMABI COLLEGE
P. VEMBALLUR, THRISSUR, KERALA
(AFFILIATED TO THE UNIVERSITY OF CALICUT)

AUGUST 2024

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P. Vemballur
19.08.2024

Reenank

Principal

M.E.S. ASMABI COLLEGE KODUNGALLUR P. VEMBALLUR

Principal in Charge
M.E.S Asmabi College
P.Vemballur

)480 2850596, 2859032
+91 9778065252
principal.mesasmabi@gmail.com
www.mesasmabicollege.edu.in
P.Vemballur P.O.-680 671
Kodungallur, Thrissur Dist, Kerala

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P. Vemballur

19.08.2024

Head of the Department

Research Department of Botany

Head of Department
Research & PG Dept. of Botany
MES Asmabi College
P. Vemballur, Thrissur Dt.
Kerala - 680 671

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P. Vemballur
19.08.2024

Dr. Amitha Bachan K.H.
Research Supervisor

Dr. Amitha Bachan. K. H.
Assistant Professor & Research Guide
Research & P.G Department of Botany
MES Asmabi College, P.Vemballur
Kodungallur, Thrissur-680671,Kerala-India

0480 2850596, 2859032
+91 9778065252
principal.mesasmabi@gmail.com
www.mesasmabicollege.edu.in
P.Vemballur P.O.-680 671
Kodungallur, Thrissur Dist., Kerala

DECLARATION

I hereby declare that the work presented in the thesis entitled **"RIPARIAN FOREST COMPOSITION, CLASSIFICATION AND MAPPING IN RELATION TO BIOCLIMATE IN THE ANAMALAI LANDSCAPE UNIT, WESTERN GHATS"** is based on the original work done by me under the guidance of Dr. Amitha Bachan K.H, Assistant Professor and Research Guide, Research and PG Department of Botany of MES Asmabi college, P. Vemballur and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis are undergone plagiarism check using **iThenticate** software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

Pooja Suresh

Place: P. Vemballur

Date: 19.08.2024

Dr. Amitha Bachan K. H.

Supervising teacher

Dr. Amitha Bachan. K. H.
Assistant Professor & Research Guide
Research & P.G Department of Botany
MES Asmabi College, P.Vemballur
Kodungallur, Thrissur-680671,Kerala-India

Dedicated to my beloved mother,
guide, and to the river

ACKNOWLEDGEMENTS

My effort would be incomplete without expressing my gratitude to all who have contributed in one way or another to the success of this research work. I use this opportunity to express my gratitude to every one of them.

First and foremost, I express my deepest regards and gratitude to my research supervisor, Dr. Amitha Bachan K.H., Assistant Professor and Research Guide, Research Department of Botany, MES Asmabi College, for his support, timely advice, valuable guidance, and encouragement throughout the study. His extensive knowledge and passion for ecology and forestry studies aided me a lot, and I am greatly obliged for all the knowledge and support he has offered me.

I convey my sincere gratitude to Dr. Reena Mohamed P.M., Principal M.E.S. Asmabi College, P. Vemballur, for her support for the successful completion of this research work. I am also thankful to Prof. (Dr.) A. Biju, former principal of M.E.S. Asmabi College, for providing the necessary facilities to carry out this research work. I would like to convey my deep and sincere gratitude to Dr. Girija T.P., Assistant Professor and Head of the Research Department of Botany, M.E.S. Asmabi College, for her constant support and encouragement. I would like to extend my gratitude to all the teaching faculties of the Research Department of Botany, M.E.S. Asmabi College, for their support.

I am beholden to Prof. (Dr.) M. Sabu, Prof. (Dr.) V.V. Radhakrishnan and Dr. A.K. Pradeep, Department of Botany, University of Calicut, for their critical evaluation, suggestions, and guidance, which are always valuable from the beginning to the end of my research work.

I would like to take this opportunity to express my heartfelt gratitude to Prof. (Dr.) Anitha C.T., Research Department of Botany, Sree Narayana College, Nattika, for the consistent encouragement, support, and inspiration.

I am indebted to the Western Ghats Hornbill Foundation for their continuous support in various stages of the work, as well as for the scholarship Sri. Hyder Sahib Memorial Research Grant (2017), in honour of Hyder Sahib (late), served as the starting point of my research journey. I would like to convey my deepest gratitude to K.M. Hyder (late).

I sincerely acknowledge the support and assistance received from the members of the Indigenous community in the field as well as the immense knowledge *and experiences they shared, especially with Mayilamani Moopan, Mr. Senthil Kumar, Mrs. Nalini, Mr. Manikya Raj, Mrs. Rama, Mr. Ayyappan, Mr. Selvan, Raman Moopan, Mr. Nandha Kumar, Mr. Chandru, Mr. Velli, and Mr. Mani. I am also thankful to the Chief Conservator of Forests and Wildlife Warden, Forest Department, Govt. of Kerala, and Divisional Forest Officers for granting permission to conduct my fieldwork.*

I owe special thanks to Research fellow, Mrs. Anitha K. T., for her support in grasping the fundamentals of GIS and mapping and to Ms. Devika M. Anilkumar for her support in my fieldwork. I am also thankful to my lab mates, Dr. Sreehari S. Nair and Dr. Gouthami V., for their help and cooperation. I extend my gratitude to all the research scholars in the Research Department of Botany and Mrs. Smrithy, Research scholar of the Research Department of English, M.E.S. Asmabi College, for their support throughout the study. I am also thankful to the laboratory staff, Mr. Mohammed Shareef M.A. and Haseena M.H., Research Department of Botany, M.E.S. Asmabi College, for their support during my research work. I would like to express special gratitude to my friends, former UG and PG students of M.E.S. Asmabi College, for their support in the field.

I am deeply indebted to Dr. Nasirudheen. T., Assistant librarian, C.H. Mohammed Koya Library, University of Calicut, Mrs. Saliha P.I., Librarian, and Mr. Mohammed Nasser, former librarian of M.E.S. Asmabi College, for providing library facilities and support. I am thankful to all the non-teaching staff of M.E.S. Asmabi College, for their support during the study.

I acknowledge the Indian Meteorological Department (IMD), Govt. of India, Pune, for providing meteorological data for the study, and I take this opportunity to sincerely acknowledge the Directorate of Collegiate Education, Govt. of Kerala, for providing ASPIRE fellowship for the period 2019–2020.

I am forever grateful to my friends and soulmates for their love and support in good and bad times, which led me to move on when things were tough. I wish to extend my heartfelt gratitude to my mother. No words are adequate to express my indebtedness towards her for the love, support, sacrifice, and everything she has done for me. I am also thankful to other family members for their support throughout the work. Finally, I owe a debt of gratitude to each person who has supported me along this journey.

Pooja Suresh

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GENERAL INTRODUCTION

1.1. The Background and the Rationale

1.1.a. Riparian forests the definition

The region between a stream's channel and a hillslope is known as the riparian zone (Seibert & McGlynn, 2005), where the presence of water significantly influences the vegetation communities. "Riparian" is a word that strikes fear in the hearts of many, anger in some, and feelings of peaceful surroundings in others; it is a word that means many things to different people but is rarely understood (Elmore, 1989). The word "Riparian" originated from the Latin word "Ripa," which means the bank of a river, pond, or lake of the surrounding landscape (Tabacchi et al., 1990). "Riparian area" can be defined as the "land area adjacent to the river channel from its origin up to the river mouth, where the flowing water keeps in contact or influence which is characterised from other wet habitats being variably water-filled with faster flow from minutes to weeks, seen subcontinent or landscape level with linear geometry", this can be a small portion of a river basin, defined by its spatial position in the watershed or landscape unit where its characters are determined chiefly by the geomorphic, environmental and biotic factors existing in the upstream and downstream influencing the pace of water (Bachan, 2010). Riparian landscapes make up just one-thousandth of the earth's surface and are a severely threatened or endangered ecosystem (Hynes, 1970; Bachan et al., 2022).

The biotic communities living in the riparian areas, their interaction with the immediate environment, role in the functioning of the river basin as a whole have gained more focus from the researchers of the past two decades (Naiman et al., 2000; Anbumozhi et al., 2003). The Western Ghats, especially the Kerala part, has 44 rivers within a 38,863 km^2 area of Kerala, and the riparian forest along these rivers is a vital vegetation network connecting all important landscape subunits of the Southern Western Ghats. Understanding the nature, structure, and function of these ecosystems has great significance in natural resource management.

1.1.b. Biodiversity richness of riparian forests

Riparian zones are highly complex corridors which possess several environmental processes and diverse species compositions; this ecological diversity of riparian zones is connected to changing flood regimes, geomorphological channel processes, altitudinal climatic fluctuations, and influences of uplands systems on the riparian corridor (Naiman et al., 1993). They provide links to fragmented and degraded landscapes stretching across forest and urban. When a land faces extreme levels of degradation the only available natural vegetation will be in its riparian stretch. By offering refuge, breeding grounds, food, and connections for arthropods, amphibians, mammals, and birds, riparian linear landscapes help to preserve terrestrial biodiversity in agricultural landscapes; consequently, riparian buffers are essential as islands of biodiversity (Giraldo et al., 2022).

Rivers, from their origins to their mouths, provide diverse ecosystems and are a key source of biodiversity (Tockner & Stanford, 2002). The Earth's most unique landscape features are riparian flood plains and their corridors, distinguished by incredible biodiversity and productivity (Ward et al., 2002). The density, diversity, and structure of the vegetation, along with the riparian zones and wetland landforms, often fulfil the needs of many wildlife species and offer more habitat niches than any other habitat. Thus, compared to surrounding terrestrial habitats, riparian ecosystems are a centre of biodiversity because of the abundance of species and the density of wildlife (Odum, 1979; Oakley et al., 1985; Tye, 2011). Climate, altitudinal gradients, upland impacts, flood regimes, and geomorphic channel processes all significantly impact the biological richness of riparian corridors (Naiman et al., 1993). Strong spatial and temporal biophysical connection with nearby riparian and upland systems helps to sustain their complexity, biodiversity, and unique ecological roles and serve as climatic refugia for plants (Naiman et al., 2013; Zhang et al., 2023a).

The high biodiversity of riparian zones can be linked to cool, moist climate, high productivity, and complex habitat (Olson et al., 2007). Under certain conditions, organisms and processes find refuge in riparian corridors (Naiman et al., 2005). Since it derives from terrestrial and aquatic populations, riparian regions have a vast species pool, and many species can survive because the natural disturbance regime prevents competitive exclusion. Some species are only found in the riparian corridor, while others use it for specific stages of their life cycles (Decamps & Tabacchi, 1992). Fostering spatial and temporal heterogeneity, enabling the coexistence of plants with a range of life history strategies and flood disruption can help riparian habitats retain high levels of biodiversity (Richter & Stromberg, 2005; Cheng et al., 2007; Wang et al., 2023). Even in Central Europe, where species diversity is often low, floodplains are the hotspots of biodiversity (Naiman et al., 1993; Schnitzler, 1994). The most significant predictor of species richness and abundance was buffer width, and the width responses varied significantly across taxa (Deere et al., 2022).

The uncontrolled, minimally regulated, and refilled areas of regulated rivers have the highest biodiversity of riparian zones. The high biodiversity of these remnant areas results from better natural flow and sediment deposition, as well as a legacy of native species (Johnson, 2002). Undisturbed areas have the highest plant species biodiversity (Srivastava & Singh, 2013). Also, Riparian areas with trees support fewer weed species (Boutin et al., 2003). The floristic diversity of riparian zones was proven through significant floristic research from different river basins of the Western Ghats, these include studies on the Chalakudy River basin (Bachan, 2003; Bachan, 2005; Bachan, 2010; Bachan & Pradeep, 2010; Bachan & Pooja, 2017; Bachan et al., 2022); Valapattanam river (Sreedharan, 2005); Pamba river basin (Jobi, 2012); Meenachil river basin (Varghese, 2014); Kechery river basin (Jobi, 2016); Cauvery River basin (Jayaram, 2000; Sunil et al., 2009; Sunil, 2012; Sunil et al., 2016); Thuppanad river (Jisha & Nair, 2018); Tambiraparani River (Johnsingh & Joshua, 1989; Angel, 2018); Thutha River (Jisha, 2020); Tungabhadra River (Siddeshwari & Kotresha, 2023) and the Chaliyar river basin (Mahesh, 2023).

Odonates play a vital function as prey for birds, frogs, and other animals and as significant predators of other insects in the riparian ecosystem's food chain. Odonates assist people in evaluating the health of the riparian ecotone as bioindicators (Kulkarni & Subramanian, 2013; Sakai et al., 2019; Chourasia et al., 2020). High Odonates diversity and endemism were observed in streams flowing through evergreen forests. Thus, it indicates riparian ecosystem health (Subramanian et al., 2008). Odonata, by itself, could be helpful for biomonitoring connected to riparian stream sides (Cheri & Finn, 2023; Mendoza-Penagos et al., 2021). The quality of the terrestrial and aquatic ecosystems was similarly correlated with the abundance of adult Odonates (Calvao et al., 2023), and they require dense native riparian forests for perching and survival (Bose et al., 2021).

Riparian forests also influence fish diversity and assemblages (Davies & Nelson, 1994; Penczak et al., 1994; Penczak, 1995; Kennedy et al., 2000; Naylor et al., 2012; Santos et al., 2015; Teixeira-deMello et al., 2016; Arthington et al., 2019; Nikolaus et al., 2022). The most significant factors affecting fish communities were riparian watershed and reach-scale features (Stewart et al., 2001). In riparian and floodplain environments in tropical areas, frugivorous fish play a significant role in the plant community's seed distribution and reproductive dynamics (Correa et al., 2015). The fish population generally declines with the extension of the riparian non-forested patch (Jones et al., 1999). Adequate protection for the fish populations should be provided by keeping riparian buffer strips undisturbed (McDowall et al., 1977). Proper restoration of riparian forests along streams will benefit stream fishes, and it is sufficient to safeguard riparian forests to preserve stream fauna (Leal et al., 2018; Ishiyama et al., 2020). Riparian buffers exhibited more diversity, abundance, and richness of birds than crop and pasture habitats, and most of the assemblages of bird species were found in the riparian areas (Darveau et al., 1995; Lehmkuhl et al., 2007; Berges, 2009). Riparian zones supported more woodland-dependent bird species (Tye, 2011; Bennett et al., 2014). Bats utilise riparian areas for drinking, roosting, and foraging (Keefe et al., 2013). Compared to corresponding non-riparian regions, riparian zones have a higher diversity and overall abundance of birds and litter invertebrates (Woinarski et al., 2000; Catterall et al., 2001).

The composition of snail traits was also influenced by the riparian forest's complexity, with higher densities of snail species that lived in woody debris, leaf litter, and root zone and species that consumed detritus found in the riparian zones (Gheoca et al., 2023). Streams with various land uses had distinct stream insect diversity and community composition (Subramanian et al., 2005). Elephant disturbances have influenced the patterns and levels of riparian woody species richness and structural diversity. Even though the richness of riparian woody species showed early indications of losses caused by elephants in areas with heavy elephant disturbance, the species diversity at the landscape level remains unaltered (Gaylard, 2015). Riparian zones are also suitable habitats for many spider species (Shihabudeen et al., 2020). Diverse riparian habitats were used by freshwater turtles for nesting, feeding and overwintering (Bodie, 2001). Many amphibians live in riparian areas, with approximately one-third as stream-riparian obligatory species (Olson et al., 2007). Compared to non-native stands, riparian forests provide a better habitat for riparian reptiles and amphibians (Bateman & Merritt, 2020). Low-elevation evergreen Riparian forest of the Chalakudy River, with an extent of 2.38 km^2 (0.8%) of the total available natural riparian forests alone, is an example of the overall diversity of riparian forests in all aspects of fauna and flora. It has 696 angiosperms, of which 254 are endemics, and 33 threatened species, a rich diversity of birds (117 species), Mammals (71 species), Amphibians (14 species), Reptiles (6 endemic species), Fishes (72 species), Odonates (48 species), and Butterflies (86 Species) (Pooja et al., 2020).

Loss of biodiversity reduces an ecosystem's capacity to deliver ecological services. (Hooper et al., 2005). The riparian ecology is negatively impacted by hydrological changes, resulting in biodiversity loss and disruption in the riparian stretch (Johnson, 2002; Castello & Macedo, 2015; Zheng et al., 2023), the disappearance of plant dispersal and pollination agents (Ferreira et al., 2013), results in an increase in alien species (Man-Kyu, 2017). Increased grazing intensity in rivers was linked to a decline in the ecological state of riparian ecosystems and reduced diversity of birds, frogs, and plants that negatively impact the biodiversity of riparian and the functioning of rivers (Jansen & Robertson, 2005). Anthropogenic disturbances and exotic plant species invasion alter the structure and composition of riparian forests and decrease diversity and productivity. This results in the eradication of indigenous species, which causes a severe environmental problem since it alters the ecosystem functions of riparian zones (Nilsson & Berggren, 2000; Miyawaki & Washitani, 2004; Sunil et al., 2011; Varughese & Joseph, 2022). Maintaining or increasing the quality of surrounding landscapes can promote biodiversity movements among riparian zones and upland forests, promoting ecosystem services by riparian ecosystems (Garcia-Martinez et al., 2017).

1.1.c. Significance of riparian forests buffers

The Riparian forest is known as a "Keystone ecosystem" because it has many unique habitats greatly influenced by water (Goebel et al., 2003). Riparian forests in mountainous regions are critical for maintaining this diversity, as well as ecosystem resources and services, and it has a crucial role in the survival of both the aquatic and terrestrial ecosystems since it is an ecotone zone. They play essential roles in many facets of the biotic and abiotic systems. Riparian ecotones are generally the first to display substantial modifications that influence catchments. They are located at the lowest topographical level within catchments and acquire material, propagules, genes, and information. As a result, they can be used to track overall ecosystem health within catchments (Jacobs et al., 2013). They provide diverse habitats for many species and maintain high ecological diversity and productivity (Simon et al., 2004).

The riparian areas' regeneration process is fast due to water and nutrient availability. So, the degraded land reclamation into productive areas can be achieved faster through riparian areas. Riparian zones only comprise a small percentage of the landscape, even though they can deliver various ecosystem services at higher levels (Bentrup et al., 2012). Ecosystem services and vegetation dynamics are most widely examined in riparian zones. Detailed accounts of these aspects have already been proved by various studies (Naiman & Decamps, 1990; Naiman et al., 1993; Huerta et al., 1994; Tabacchi et al., 1996; Naiman & Decamps, 1997; Soman et al., 2007; Keeton et al., 2007; Berges, 2009; Sunil et al., 2012; Esse et al., 2019; Deepthi et al., 2019; Riis et al., 2020; Prado et al., 2022).

Healthy riparian areas can reduce the impact of climate change and anthropogenic activities (Graziano et al., 2022). Riparian buffers create thermally stable, high-humidity climatic envelopes that serve as climatic refugia (Pusey et al., 2003). For species to migrate from sensitive climatic changes, riparian buffers establish spatial connections in the lateral, longitudinal, and vertical directions (Naiman & Decamps, 1997; Nakamura, 2022). An effective way to improve climate change mitigation is to preserve and maintain the undisturbed riparian zones, indicating the severity of the hydrological decline brought on by climate change (Capon et al., 2013). The riparian cover provides shade, which regulates the temperature and photosynthetic productivity of streams (Wilkerson et al., 2006; Broadmeadow et al., 2011; Joby, 2012) and has effects on the quality of water, lowering light levels, reducing the development of undesirable plants and algae and have an impact on the life histories of fish, amphibians, and invertebrates (Gregory et al., 1991; Bowler et al., 2012; Garner et al., 2017; Barnett et al., 2018; Capon & Pettit, 2018). Riparian zones also act as dispersal systems tying together various landscapes and as a corridor of species dispersal migration and potential pollinator habitats (Merriam & Lanoue, 1990; Cordes et al., 1997; Santos et al., 2018; Deepthi et al., 2020; Peredo et al., 2023). They also provide pest control services. When riparian forests became more complex, the proportion of pest species declined, whereas, in woody riparian strips, insectivorous species increased in abundance (Maisonneuve & Rioux, 2001). In agricultural systems, wider riparian buffer strips can improve natural pest control and pollination services Cole et al. (2020).

The effects of the riparian zone on populations of plants and animals have already been proven by Klapproth and Johnson (2009). Large woody debris from riparian forests contributes to stream ecosystems and influences sediment deposition (Cummins, 1974; Mosley, 1981; Swanson et al., 1982), and they offer fish and other aquatic species a medium for biological processes (Nakamura & Swanson, 1993; Nakamura & Swanson, 1994; Pusey & Arthington, 2003). The input of riparian fruit and the locations of riparian fruiting trees can cause spatial segregation within freshwater fish communities, and the areas of riparian fruit trees act as hotspots of biotic interactions for freshwater communities and influence the distribution of stream fishes (Nogueira et al., 2023). Benthic macroinvertebrates and terrestrial invertebrate communities in flowing waters also benefit from the woody riparian forests (Popescu et al., 2021; Oester et al., 2023; Palt et al., 2023). Riparian buffer zones along streams also act as avian refuges and provide corridor services (Hennings & Edge, 2003; Lehmkuhl et al., 2007) and as preferred bird nesting sites (Dasgupta et al., 2022).

Riparian forests stabilise riverbanks through their root system; the root systems of riparian plants contribute to preserving the physical characteristics of the soil and minimising soil erosion (Gregory & Ashkenas, 1990; Cordes et al., 1997; Vargas-Luna et al., 2016; Zong et al., 2023). Riparian forests also improved the erosion resistance, substantially slowing the riverbank's lateral migration pace. The flow shear stress rate required for a given river channel migration increases with the rate of riparian vegetation cover. Also, it enhances vertical migration, resulting in a rise in total scour depth along the riverbank (Yang et al., 2018). Mixed stands of riparian woody and grass species tend to form the most stable erosion control systems (Simon & Collison, 2002). Both live and dead trees in the riverbanks serve as the stabilising factors in stream bed structure, and their removal will provoke adjustments in channel morphology. By removing obstructions, flow velocity increases, which might erode the channel bed, increase the sediment load, worsen the water quality, transfer nutrients outside the system, and damage the natural habitat (Barro et al., 1989). Thus, it also impacts the fluvial dynamics and River morphology (Perucca et al., 2007; Murray et al., 2008; Solari et al., 2016; Camporeale, 2019; Del Tanago et al., 2021; Zhu & Tsubaki, 2022). Because of its mechanical, hydrological, and hydraulic impacts, riparian forests can strengthen the stability of riverbanks. Individual soil particles form erosion on riverbanks with vegetation, whereas a large block of soil erosion occurs on riverbanks without vegetation (Li et al., 2023). Upland wildfires can be controlled, and their geographical extent can be limited by riparian vegetation, which can serve as a natural barrier to wildfire (Pettit & Naiman, 2007).

Riparian forests assist in the maintenance of water quality (Maridet, 1995; Hanson, 1997; Jones et al., 1999; Kuusemets et al., 2001; De Souza et al., 2013). Moreover, it is more influenced by riparian buffer length than by width to enhance the protection of river water quality and other ecosystem services. Wide and long riparian forests are ideal (Anbumozhi et al., 2003; Brumberg et al., 2021). Riparian forests affect stream water quality in several ways, from direct chemical absorption by riparian plants and recycling as modified plant litter on soil (Dosskey et al., 2010). Even during storm surges, slowed surface runoff improves groundwater recharge through riparian soils (Osborne & Kovacic, 1993; Castelle et al., 1994). The propagation of flood waves is also influenced by riparian forests (Welsch et al., 2000; Anderson et al., 2006). It helps minimise floods, soil erosion, and water pollution (Davis & Naumann, 2017), helps lower flood velocities and enhances the flow to lower reaches. In a landscape's cultural and traditional aspects, riparian forests are always an essential component (Sunil et al., 2011).

The diversity of plants in agricultural landscapes is increased by the small strips of riparian vegetation (Boutin et al., 2003). Wetlands and riparian forests are significant carbon sinks that can store carbon for a long time (Cierjacks et al., 2010; Sutfin et al., 2016). Sediments carried by overland flow from hill slopes are trapped in grassy riparian zones (Magette et al., 1989). At the local level, it regulates processes involving surface and subsurface flow (Pasche & Rouve, 1985; Bren, 1993; Darby, 1999; Thomas & Nisbet, 2007) and contributes to the energy flow in stream ecosystems (Liao et al., 2022).

The riparian zones serve as a source and a sink for matter and energy (Tabacchi et al., 1998). Riparian forests drastically lower nutrient runoff and promote nutrient cycling (Meyer et al., 1998; Tabacchi et al., 2000). Thus, for nutrients, sediment, and pollutants in agricultural and urban runoff they act as filters, transformers, sources, and sinks (Lowrance et al., 1984; Welsch, 1991; Malanson, 1993; Vought et al., 1994; Naiman et al., 1998; Mander et al., 2008). The process of denitrification can effectively remove nitrogen from riparian areas (Boz & Gumiero, 2015; Lyu et al., 2021), riverside stress reduction in industrially polluted regions (Abbas et al., 2023), and actively engage in eutrophication reduction in the waterbody (McClain et al., 2003).

The water availability in riparian zones influences the maintenance of trophic structure, species distribution, and trophic interaction in food webs (Wootton et al., 1996). Local riparian buffers can maintain trophic structure even in watersheds with high agricultural intensity (Champagne et al., 2022; Zhang et al., 2023b). Compared to terrestrial lands, riparian forests conservation can be utilised to connect protected areas; they act as corridors between forest habitats and populations (Ward et al., 2002; Fremier et al., 2015), breeding habitats for animals and birds (Rottenborn, 1999; Blair, 1996; Cockle & Richardson, 2003). Humans greatly benefit from the favourable outputs of clean rivers on human health; the quality of river waters, high biodiversity, and riparian habitat structure benefit human life. Moreover, after inhaling plant-emitted volatile organic compounds, riparian forests can strengthen human immunity and river waters, including plant metabolites, which are components of traditional medicines. Thus, river therapy treats psychological stress and physical illness (Roviello et al., 2022). Rivers are more attractive to people because of a high sense of wilderness (Brown & Daniel, 1991; Bowker & Bergstrom, 2017). Riparian landscapes are the most productive and important of all lands, even though they only comprise less than 1% of the land area (Chaney et al., 1990). Recreational pursuits increase the presence of humans in riparian areas, which can worsen biological incursions (Bodie, 2001; Zelnik et al., 2020). Riparian forests are considered biologically rich but are currently at risk (Bachan & Pooja, 2017; Bachan et al., 2022). Thus, it must be protected to fulfil all the ecosystem services provided by riparian zones.

The present thesis brought out heterogeneity in the bioclimatic zones of the Anamalai landscape; the bioclimatic zones and the riparian forests were mapped for each river basin within, described the heterogenic riparian forest compositions based on phytosociological analysis, and systematically classified. Hence, the present work filled the gaps in studies on riparian forest composition, classification and distribution across various river basins within each bioclimatic zone of the Anamalai landscape unit of the Western Ghats.

1.2. Objectives

Studies that analyse the impact of ecosystem services provided by riparian forests have recently focused greater attention on riparian forests. Therefore, being in the biologically rich Southern Western Ghats, the Anamalai landscape has more to reveal. To fulfil these, the study has three main objectives, which are listed below,

1. Understand heterogeneity in the bioclimatic regimes within the Anamalai landscape
2. Mapping of Riparian forest vegetation in different bioclimate in the Anamalai landscape
3. Understanding Riparian community compositions for each bioclimatic zone and its classification into riparian forest types and subtypes

1.3. Significance of the study

The riparian zones are important vegetation and animal corridors establishing connections between forest and urban areas that are fragmented and degraded. Understanding the composition and classification of riparian forest types within the Anamalai landscape is essential for efficient resource management and conservation planning. Understanding heterogeneity in the bioclimate, composition and distribution of riparian forest of each river basin across the Anamalai landscape provides valuable data for developing conservation programs and sustainable management of riparian zones. The prepared riparian forests maps, which give precise information on the distribution of each river basin's dense, medium-dense and degraded riparian forests, could help prioritise riparian zones for conservation and restoration by each forest and administrative department across the landscape. The identified and mapped degraded riparian areas can be selected for ecorestoration in future.

The Western Ghats are the source of many West and east-flowing rivers, even though studies of riparian forests have been rare in the Indian region, especially from the Western Ghats. After recognising their ecological significance, riparian forests have gained attention in recent years. Hence, the present study on bioclimatic heterogeneity of the Anamalai landscape, understanding the composition and mapping of the riparian forest within each river basin, one of the important landscapes of the Southern Western Ghats, can contribute to river basin and riparian zone management and conservation planning.

1.4. Study area -The Anamalai landscape

The Anamalai landscape is a significant region in the Southern Western Ghats, starting from the southern part of the Palghat gap and extending up high ranges. ‘Anamalai’ means Elephant hills (‘Ana’ means ‘elephant’ and ‘malai’ means ‘hills’). It is located in Thrissur, Palakkad Ernakulum, and Idukki districts of central Kerala and the Coimbatore district of Tamil Nadu. The area includes important hill valleys and forests such as Nelliyampathy Hills and Chimmony Wildlife Sanctuary in the north, Thrissur, Chalakudy –Vazhachal Forests in the west, Parambikulam Tiger Reserve located almost centre of the landscape, part of Malayattur- Mankulam Forest Divisions, Eravikulam-Anamudi – Chinnar, Munnar region in the south as part of Kerala state and Topslip – Valparai region and portions of Indira Gandhi Wildlife Sanctuary of Tamil Nadu in the East.

1.4.a. Profile characterisation of the Anamalai landscape

Anamalai landscape is administratively divided into seven forest divisions (Thrissur forest division, Chalakudy forest division, Vazhachal forest division, Malayattur forest division, Mankulam forest division, Munnar forest division, and Nemmara forest division), five Wildlife sanctuaries (Peechi-Vazhani Wildlife sanctuary, Chimmony Wildlife sanctuary, Parambikulam Wildlife sanctuary, Chinnar Wildlife sanctuary of Kerala and Indira Gandhi Wildlife sanctuary of Tamil Nadu), one bird sanctuary (Thattekad Bird sanctuary) and one National Park (Eravikulam National Park) (Fig.1.1.).

The three-dimensional view of the Anamalai landscape provided in fig. 1.2. indicating that the landscape covers different types of elevation gradients from lower to higher and very higher elevation regions, that is, 30 to 100 m areas in the Thumburmuzhy- Athirapilly region, Nelliyampathy - Valparai higher elevation regions and 2000 to 2695m elevations in the Munnar-Anamudi areas. The Elevation, Slope, Aspect and Contour maps (Fig 1.3 – Fig 1.6) developed help better understand the terrain features of the Anamalai landscape, and that are used well in the delineation of bioclimate and riparian forests across the landscape (in Chapters 3 and 4 of the thesis).

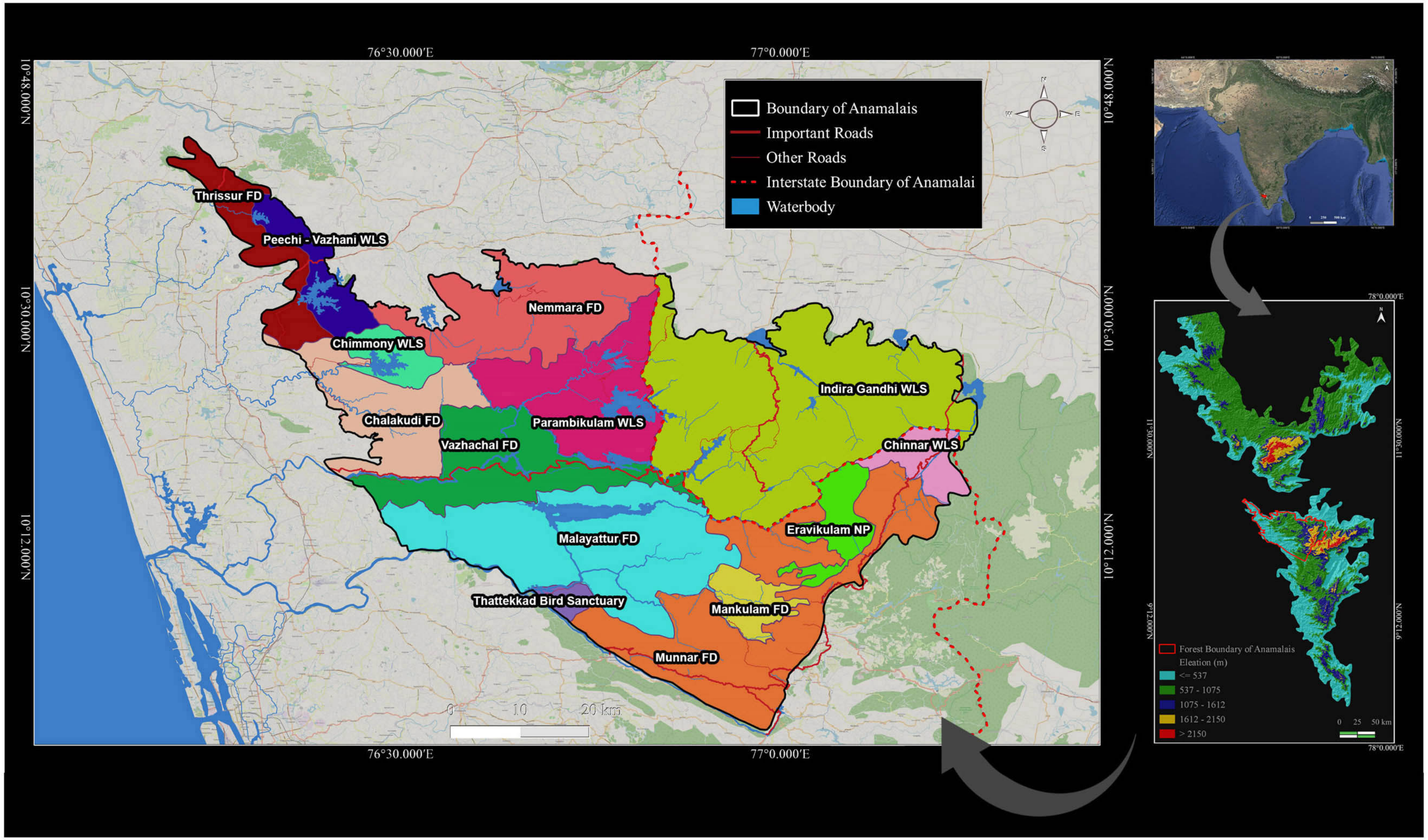


Fig. 1.1. Physical map of the Anamalai landscape.

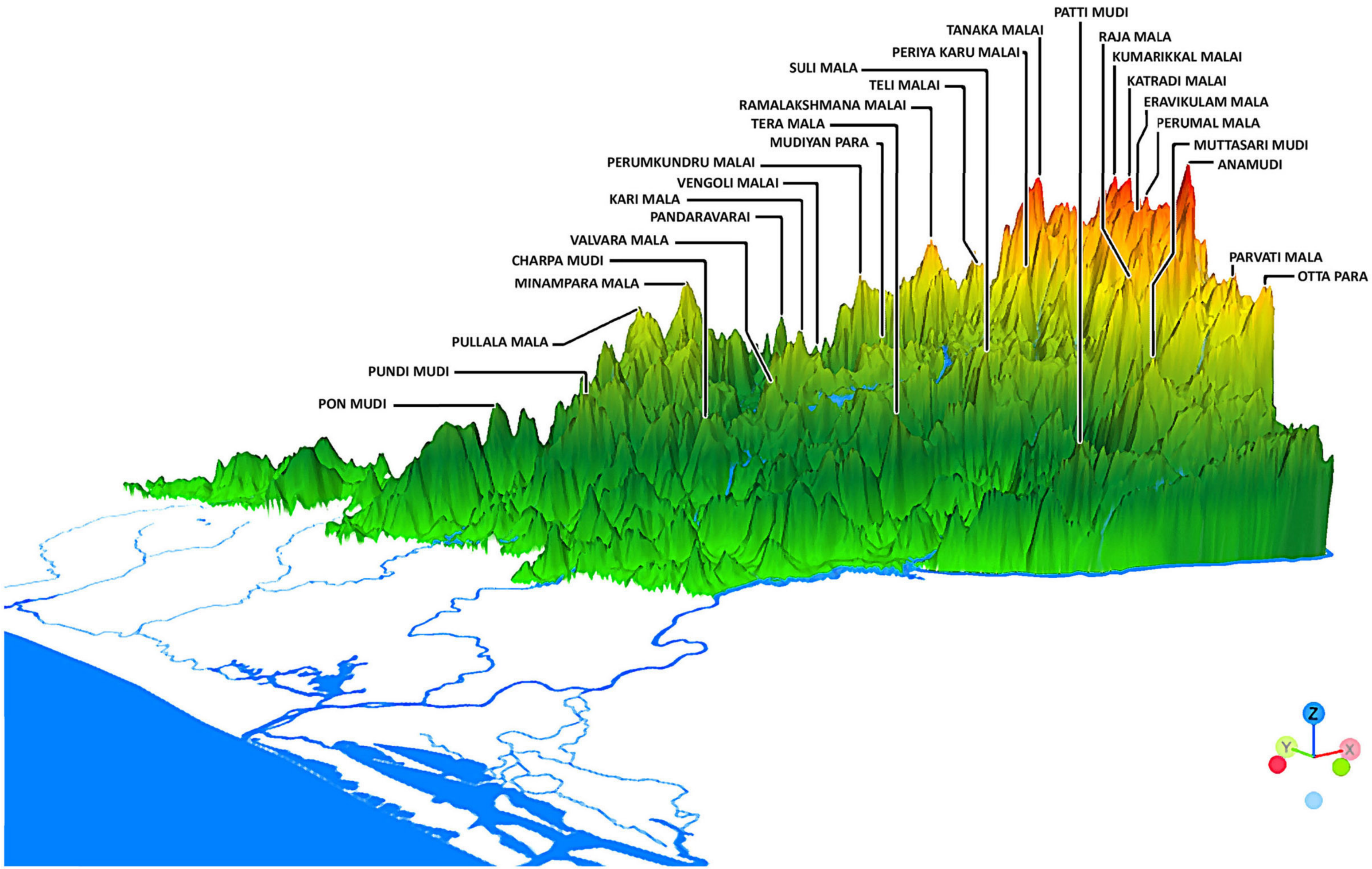


Fig. 1.2. Three-dimensional view of the Anamalai Landscape.

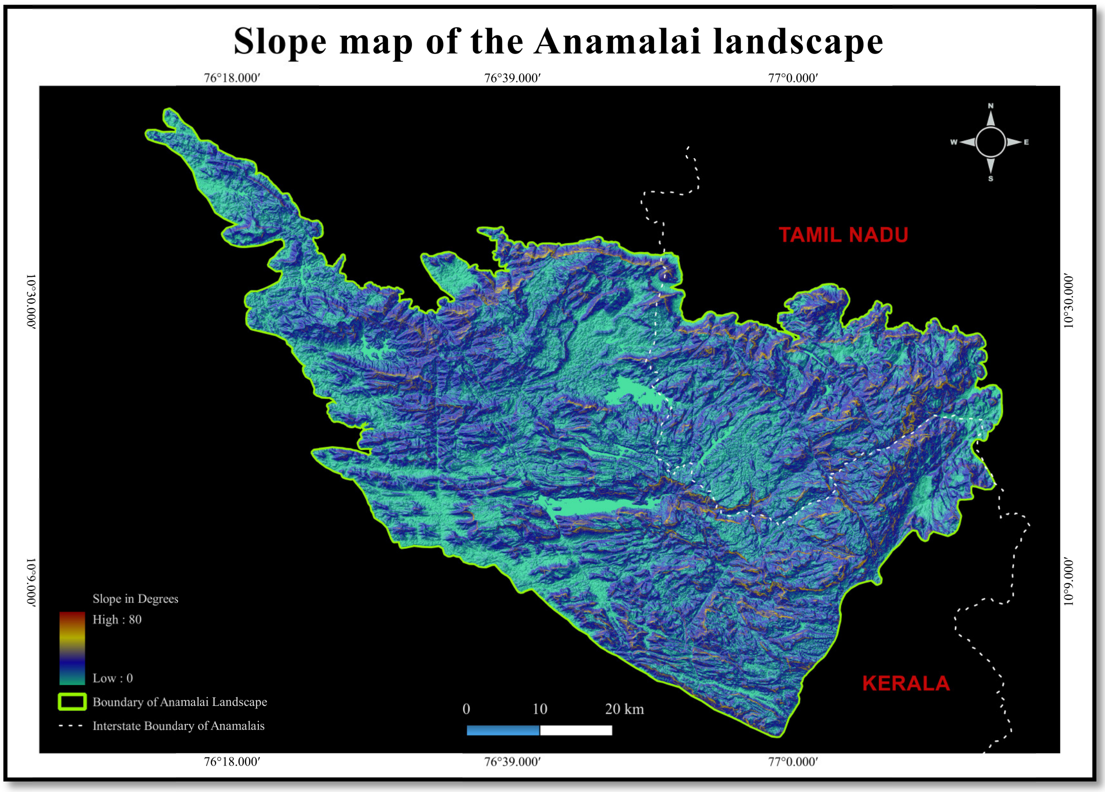


Fig. 1.3. Slope map of the Anamalai landscape

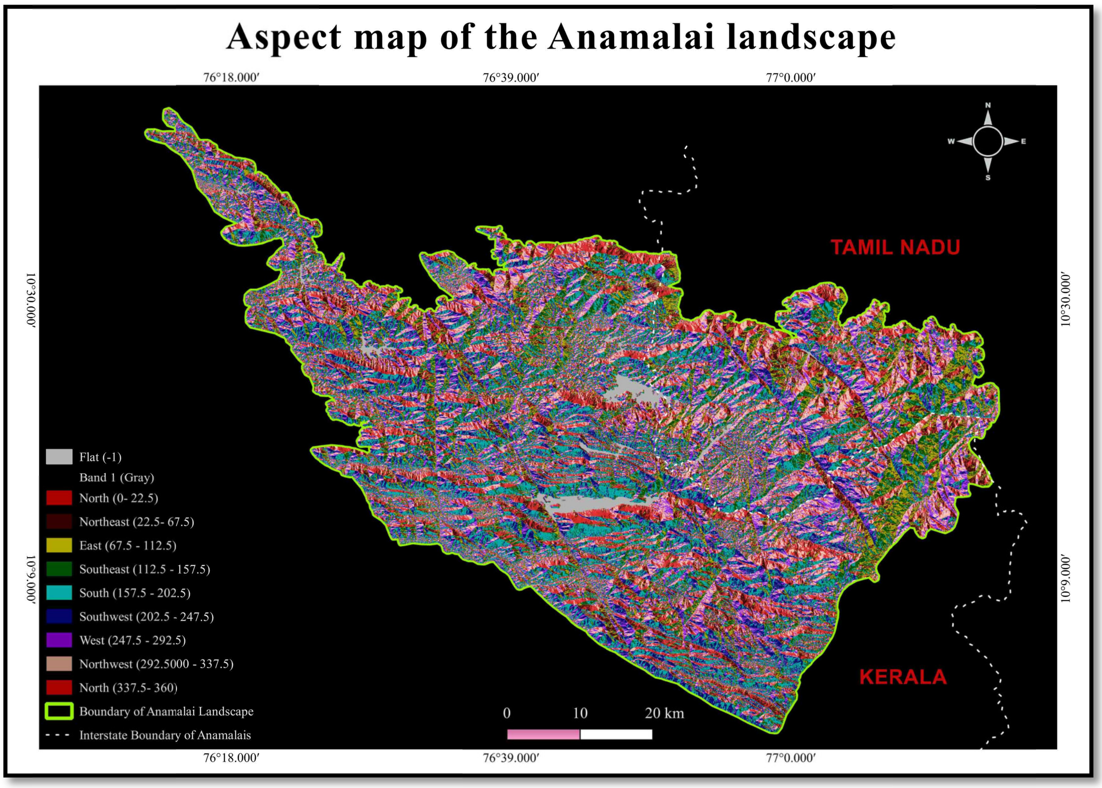


Fig. 1.4. Aspect map of the Anamalai landscape

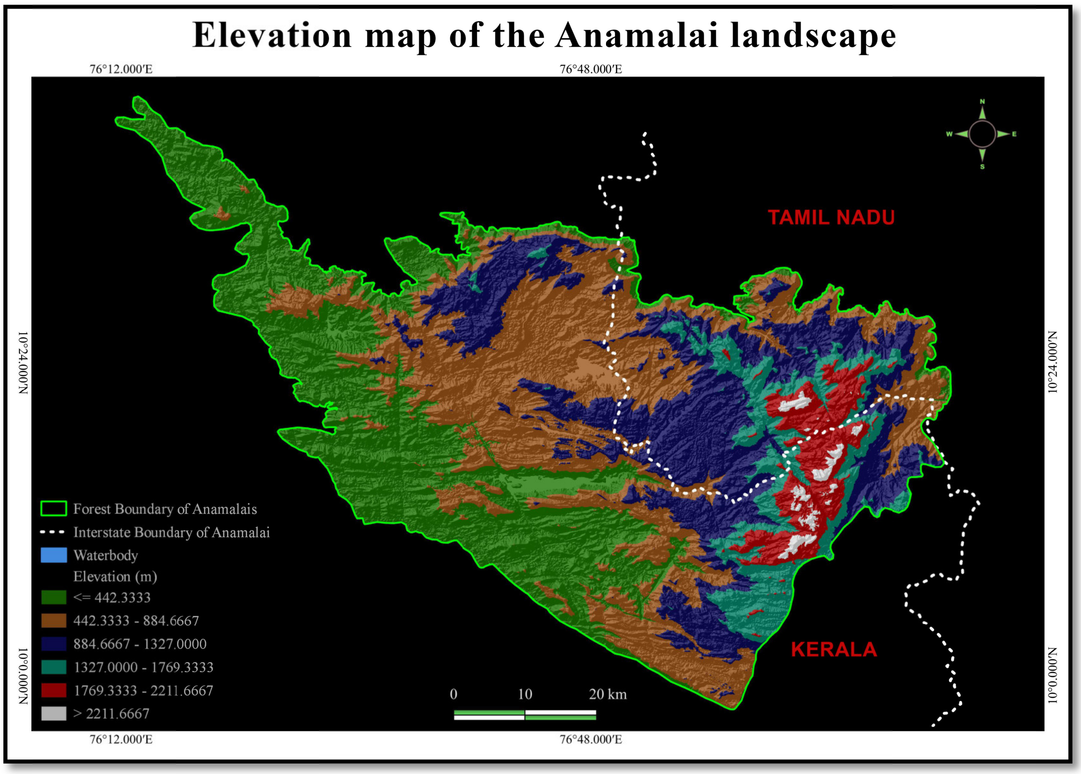


Fig. 1.5. Elevation map of the Anamalai landscape

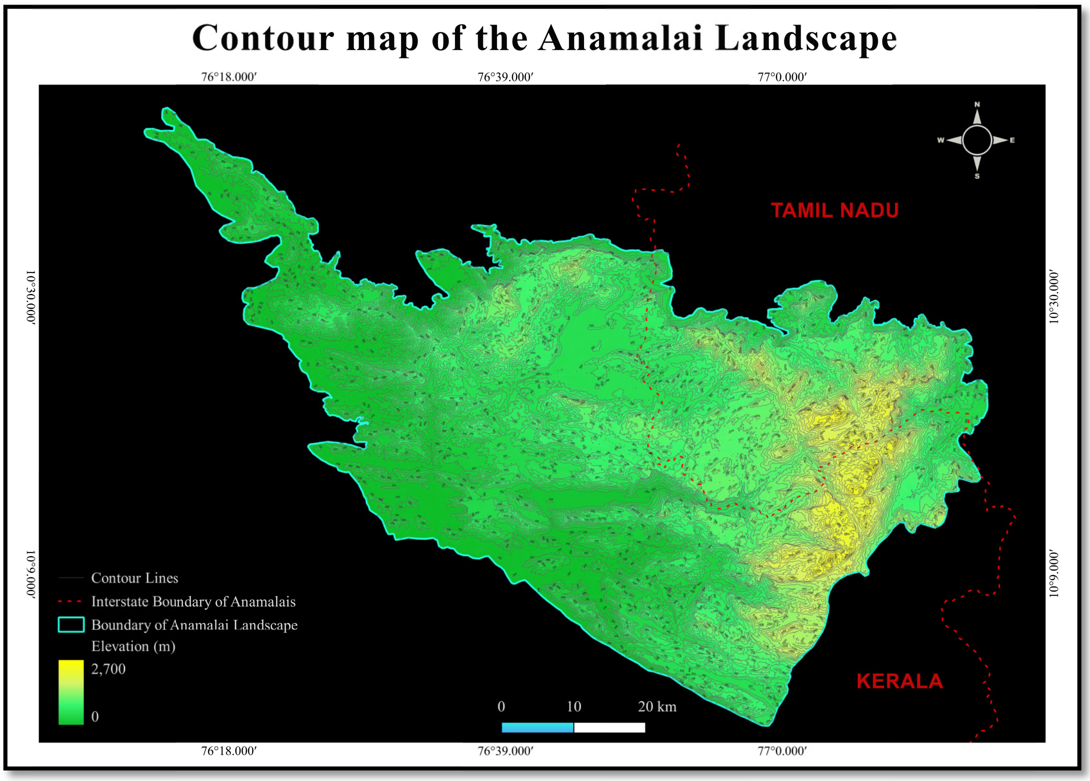


Fig. 1.6. Contour map of the Anamalai landscape

1.4.b. Vegetation of the Anamalai landscape

Understanding the existing vegetation and its heterogeneity in the landscape adjacent to the targeted riparian forests is essential since the riparian forests are usually seen as a continuum of this mosaic. This, along with the bioclimate of each subunit, provides an idea of the primary vegetation and its succession of degradation type within. The QGIS 3.22 software was utilised primarily to map and analyse the Anamalai landscape's vegetation as a prior requisite to riparian forest mapping. A detailed vegetation map of the landscape has been derived from the IFP Simple 14 Class Vegetation classification by Renard et al. (2010) to determine each river basin's nearby land use and vegetation classes to support and enhance the precision of riparian forest mapping.

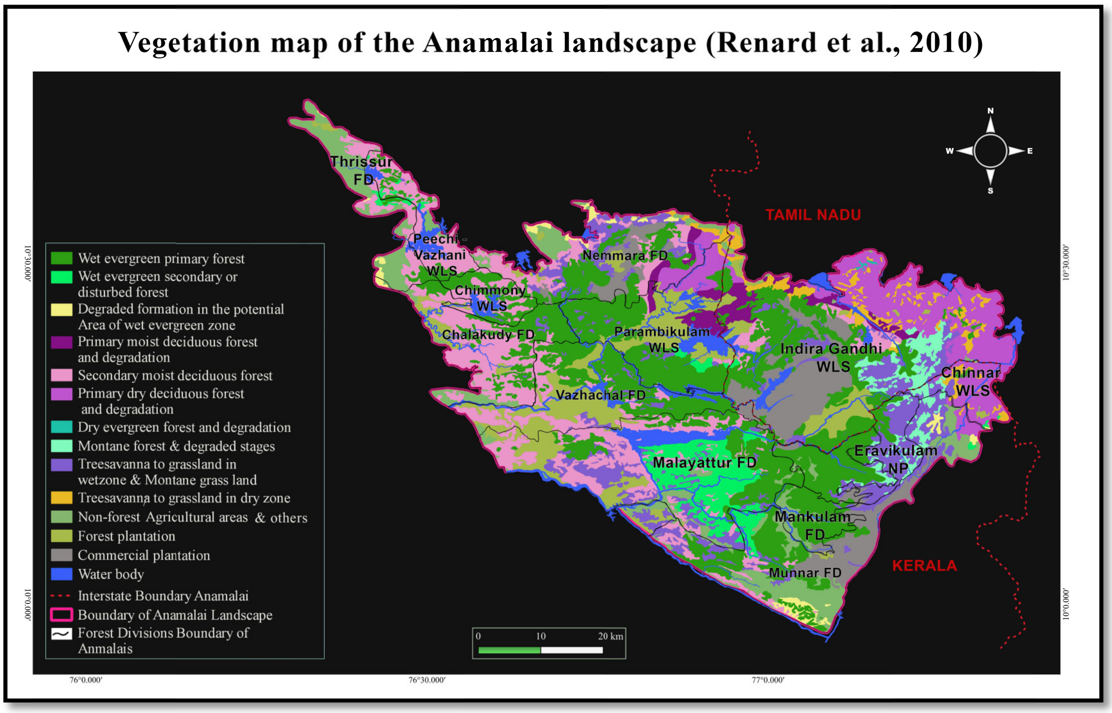


Fig. 1.7. Vegetation map of the Anamalai landscape from IFP simple 14 class vegetation classification

Table 1.1. Major Vegetation types of the Anamalai Landscape

Sl. No.	Vegetation Type	Area (km^2)
1	Wet evergreen primary forest	1050.87
2	Wet evergreen secondary or disturbed forest	169.52
3	Degraded formation in the potential area of wet evergreen zone	38.01
4	Primary moist deciduous forest and degradation	84.37
5	Secondary moist deciduous forest	648.92
6	Primary dry deciduous forest and degradation	341.09
7	Dry evergreen forest and degradation	2.68
8	Montane forest and degraded stages	78.84
9	Tree savanna to grassland in wet zone + Montane grassland	433.4
10	Tree savanna to grassland in dry zone	102.29
11	Forest plantations	401.63
12	Commercial plantations	351.2
13	Non-forest /Agricultural areas and others	358.55
Total		4061.37
14	Reservoirs and Rivers	138.63
Total		4200

According to the present study, the Anamalai landscape has a total 4200 km^2 area. Within this boundary limit landscape covers thirteen vegetation types covering 4061.37 km^2 area according to vegetation types derived from IFP Simple 14 Class vegetation maps of South India that were digitised by Renard et al. (2010) (Fig. 1.7.). QGIS 3.22 software was used to extract the vegetation, prepare the maps, and estimate the extent of each vegetation type. Higher vegetation cover by Wet evergreen primary forest 1050.87 km^2 (25.02 %) followed by Secondary moist deciduous forest 648.92 km^2 (15.45%), Tree savanna to grassland in the wet zone and Montane grassland 433.40 km^2 (10.32%), Forest plantation 401.63 km^2 (9.56%), Non-forest/ Agricultural and other land use areas 358.55 km^2 (8.54%), Commercial plantation 351.20 km^2 (8.36%), Primary dry deciduous forest and degradation 341.09 km^2 (8.12 %), Wet evergreen secondary or disturbed forest 169.52 km^2 (4.04%), Tree savanna to grassland in dry zone 102.29 km^2 (2.44%), Primary moist deciduous forest and degradation 84.37 km^2 (2.01%), Montane forest and degraded stages 78.84 km^2 (1.88%), Degraded formation in the potential area of wet evergreen zone 38.01 km^2 (0.91%), the lowest area covered by Dry evergreen forest and degradation 2.68 km^2 (0.06%).In addition, the Reservoirs and main rivers occupy 138.63 km^2 (3.30 %) of the Anamalai landscape (Table 1.1.).

1.4.c. River basins of the Anamalai landscape

The Anamalai landscape (4200 km^2) includes six river basins such as Chalakudy, tributaries of Karuvannur River (Chimmony-Mupli), Idamalayar and Pooyamkutty tributaries of Periyar River, portions of the Kechery River, tributaries of Bharathapuzha (Aliyar), Pambar and its tributary Chinnar. The Periyar basin, which is represented by the tributaries Idamalayar and Pooyamkutty, covers the highest basin area (1465 km2), followed by the Chalakudy basin (1228 km^2), one of the important rivers of the Anamalai landscape, rich in riparian forests and is an inclusive basin that completely within the Anamalai landscape unit. Each river originates from the higher elevations of the Anamalai landscape and travels through different forest divisions, preserving the diversity and richness of the landscape and acting as a water source for the survival of agricultural operations of the lower plains. A detailed table of information on each river basin obtained from the publication of CWRDM (1995) and the basin area of each river basin within the Anamalai landscape delineated from the present study is given in Table 1.2.

Table 1.2. River basins of the Anamalai landscape (CWRDM, 1995)

Sl. No.	River basin	Total Basin area (km2)	Basin area within the Anamalai landscape (km^2) from present study	Origin	Total main Stream length (km)	Avg. Annual Rainfall (mm)	Avg. Annual stream flow (Mm3)
1	Chalakudy	1704	1228	Anamalai Hills Elevation - 1250 m	130	3600	1629.3
2	Periyar	5398	1465	Sivagiri Elevation - 1830 m	244	3200	4867.9
3	Pambar	384	338.3	Benmore Elevation - 1950 m	25 (Kerala)	1800	516
4	Bharathapuzha	6186	679.25	Anamalai Hills Elevation - 1964 m	209	2300	5082.9
5	Karuvannur	1054	411.28	Pumalai Elevation - 1100 m	48	3200	1398.3
6	Kechery	401	78.17	Machada malai Elevation - 365 m	51	3000	1024

1.4.c. i. Chalakudy basin

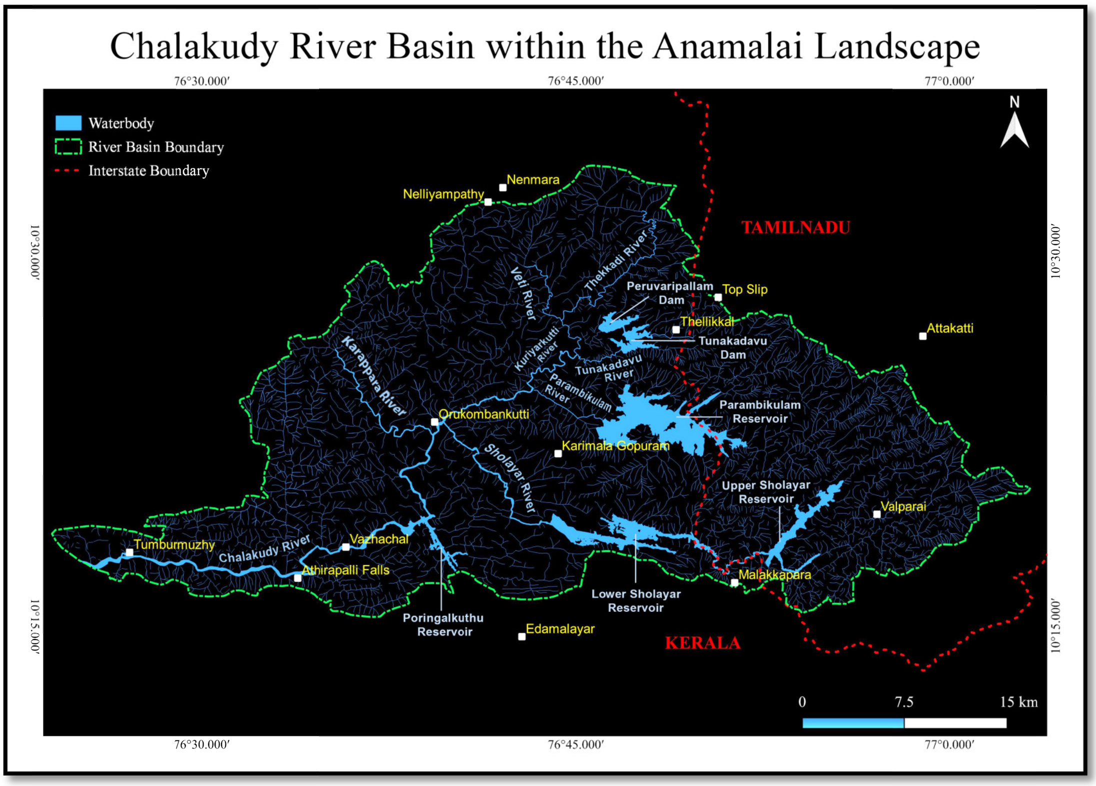


Fig. 1.8. Drainage map of Chalakudy basin within the Anamalai landscape

The river Chalakudy is the fifth-largest among Kerala's West-flowing rivers. The Sholayar, Karappara, Parambikulam, and Kuriarkutty are the four major tributaries of the Chalakudy basin, with Vazhachal and Athirappilly waterfalls in the main river. Chalakudy basin has six dams; the first is the Poringalkuthu Hydroelectric Project. Five additional dams were built on the main river as part of the Parambikulam- Aliyar interstate project (PAP), which includes the Upper Sholayar, Parambikulam, Thunakadavu, Peruvarippallam and the Kerala Sholayar Dam. As part of the Chalakudy River Diversion Scheme, there is a diversion weir in Thumboormuzhi (CRDS).

1.4.c. ii. Periyar basin

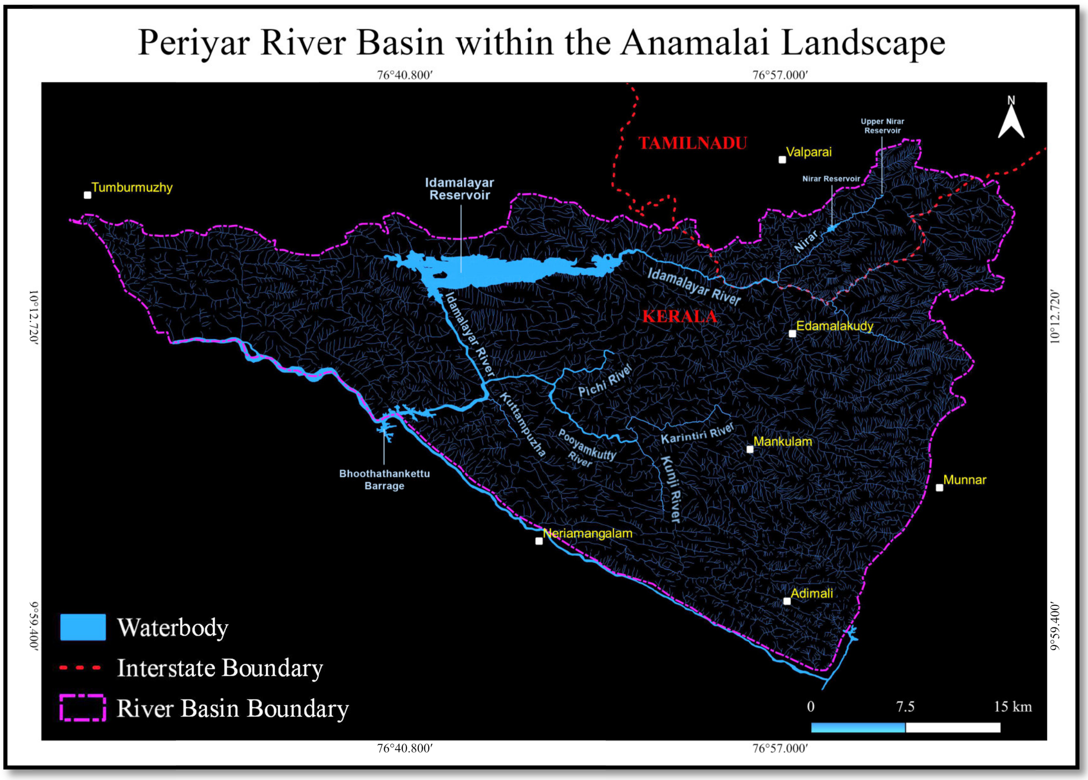


Fig. 1.9. Drainage map of Periyar basin within the Anamalai landscape

Periyar, the longest river in Kerala, travel a total distance of 244 km. Two of the major tributaries of the Periyar basin that come within the Anamalai landscape boundary are the Idamalayar and there are two important power projects within the landscape for the Periyar River: Idamalayar and Boothathankettu. Idamalayar reservoir tail waters merge with Pooyamkutty River and flow downstream, and subsequently, Kuttampuzha River and Periyar main river join and flow into Boothathankettu dam. Then the river travels through the plains along Kalady, up to Aluva, where the river divides into the Marthanadavarma River, which drains into Vembanad backwaters and the Mangalapuzha which joins the Chalakudy River towards the Arabian Sea.

1.4.c. iii. Pambar basin

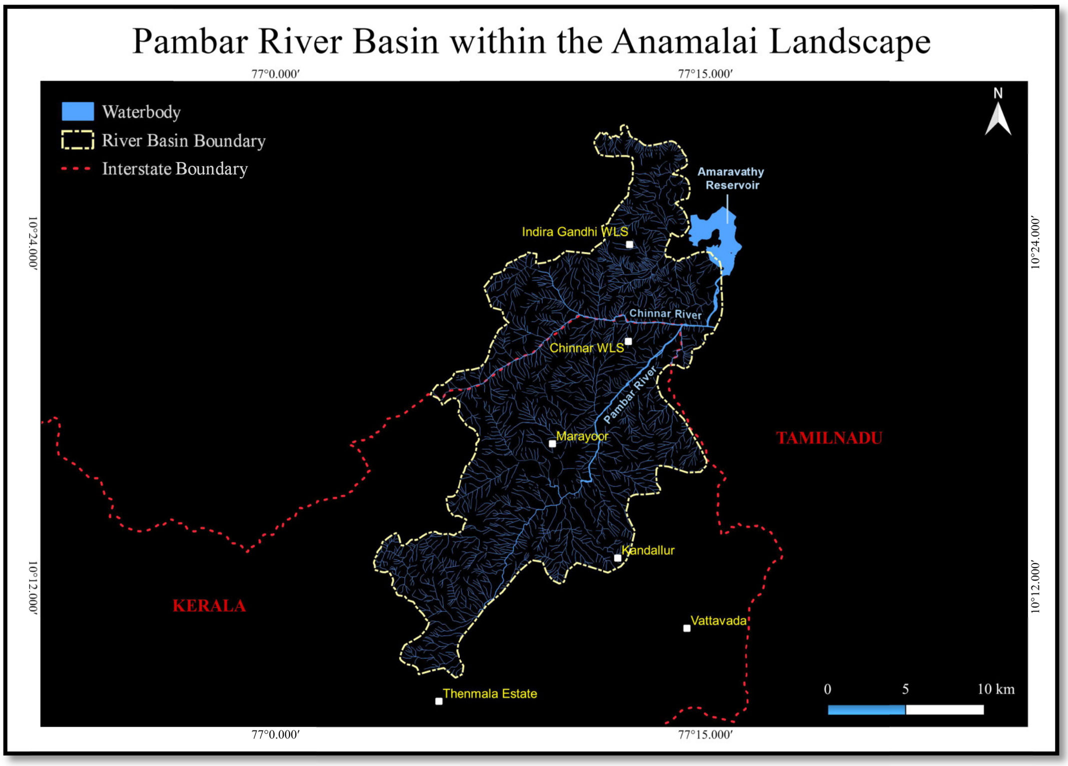


Fig. 1.10. Drainage map of Pambar basin within the Anamalai landscape

The Pambar River is a subbasin of the Amaravati River in Tamil Nadu, a major tributary of the Cauvery River. Pambar is one of three east-flowing rivers in Kerala. Originating from Benmore at an elevation of 1950 m, the river travelling through the rain shadow region of the Southern Western Ghats in the eastern slopes of the Idukki district of Kerala and meets the Chinnar River in downstream areas of the Chinnar Wild Life Sanctuary, where they merge to form the Kootar river. And flows towards the Amaravathy reservoir in Tamil Nadu, which merges into the Amaravathy River, then joins the Cauvery River, and discharges into the Bay of Bengal. The downstream portions of the basin receive less rain than the relatively wet upstream part due to the rain shadow effect.

1.4.c. iv. Bharathapuzha basin

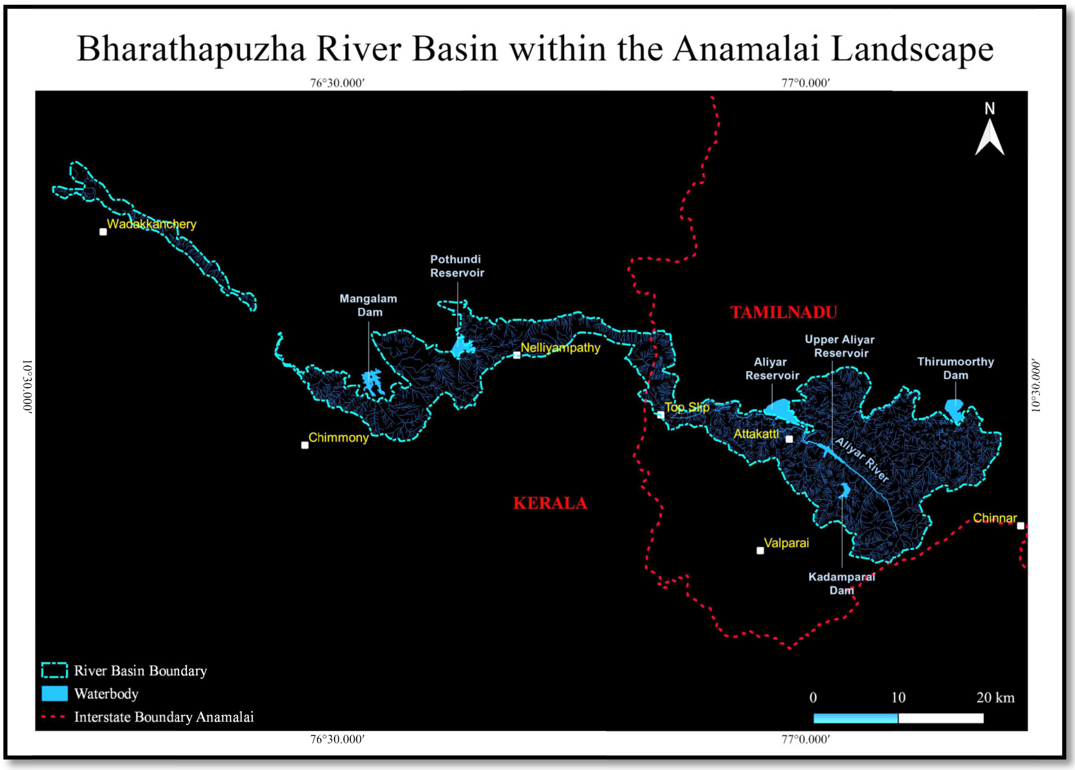


Fig. 1.11. Drainage map of Bharathapuzha basin within the Anamalai landscape

The Bharathapuzha River originates from the eastern slopes of the Anamalai hills in Tamil Nadu. The only river feeding the Bharathapuzha basin within the Anamalai landscape is the Aliyar River, which has two irrigation projects: Upper Aliyar and Lower Aliyar reservoirs. The other one is the Kadamparai reservoir, which is nourished by the Kadamparai River, a small tributary of the Aliyar River. The Aliyar River flows into Kerala from the Northwest direction, where it meets the Bharathapuzha and reaches the Arabian Sea at Ponnani in Kerala. The lower Aliyar, Tirumurthi, Mangalam, and Pothundi irrigation projects in the Bharathapuzha river basin demarcate the northern boundary of the Anamalai landscape.

1.4.c. v. Karuvannur basin

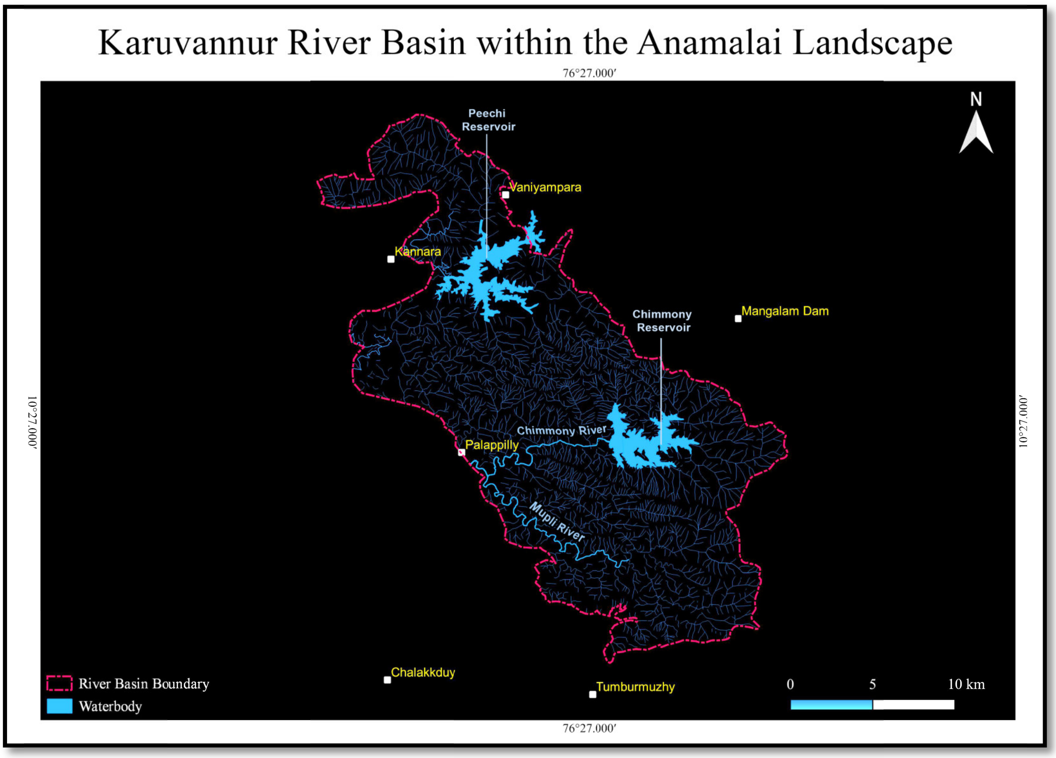


Fig. 1.12. Drainage map of Karuvannur basin within the Anamalai landscape

Karuvannur River basin is a smaller river of Kerala with a main stream length of 48 km and originates from Pumalai at an elevation of 1100 m (CWRDM, 1995). The Manali and the Kurumali are the two main tributaries that nourish the Karuvannur River. The Chimony and Muply Rivers are the Kurumali River's two important tributaries. They flow through the Peechi and Chimmony Wild Life Sanctuary of the Thrissur district of Kerala. Their catchment area has two dams: Chimmony Dam across the Chimmony River and Peechi Dam over the Manali River. Within the Anamalai landscape limit, only the Chimmony and Mupli Rivers and the Peechi Dam of the Manali River of the Karuvannur basin are situated. The Manali and Kurumali rivers join near Arattupuzha in the Thrissur district, where they continue to flow as the Karuvannur River and pass through the Kole Wetlands, then joins the Conolly Canal and discharges into the Arabian Sea.

1.4.c. vi. Kechery basin

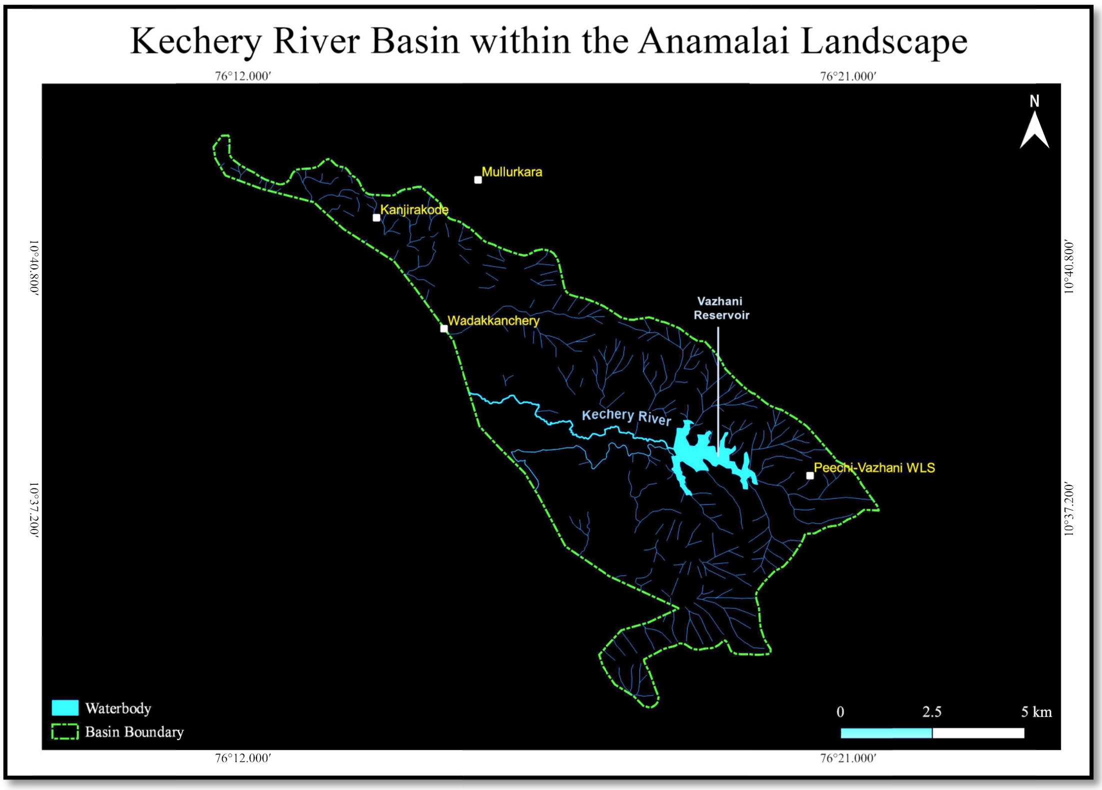


Fig. 1.13. Drainage map of Kechery basin within the Anamalai landscape

Kechery River, also known as Aloor River, has a total mainstream length of 51 km, of which 7.94 km is only inside the Anamalai landscape boundary. It originates from Machadamalai in the Southern Western Ghats at an elevation of 365 meters. Chundalthodu is the major tributary of the Kecheri River (CWRDM, 1995). It has a 401 km^2 basin area and discharges into the Arabian Sea. On the Kechery River, the Vazhani irrigation project is located, and the flood waters from the river are released into the low-lying Kol lands.

Fig. 1.14 to 1.19. displays the riparian zones of six river basins of the Anamalai landscape. Detailed descriptions of the bioclimate, riparian forest cover and riparian forest compositions of each river basin within the Anamalai landscape are covered in detail in the respective chapters of the study.

Fig. 1.14. Chalakudy basin within the Anamalai landscape: A. Sholayar River; B. Parambikulam; C. Kuriyarkutty River; D. Karappara River; E. Upper Sholayar dam, Tamil Nadu; F. Kerala Sholayar dam & reservoir; G. Parambikulam reservoir; H. Downstream to Poringalkuthu reservoir; I. Vazhachal; J. Athirappilly waterfalls; K. Thumboormuzhi weir.

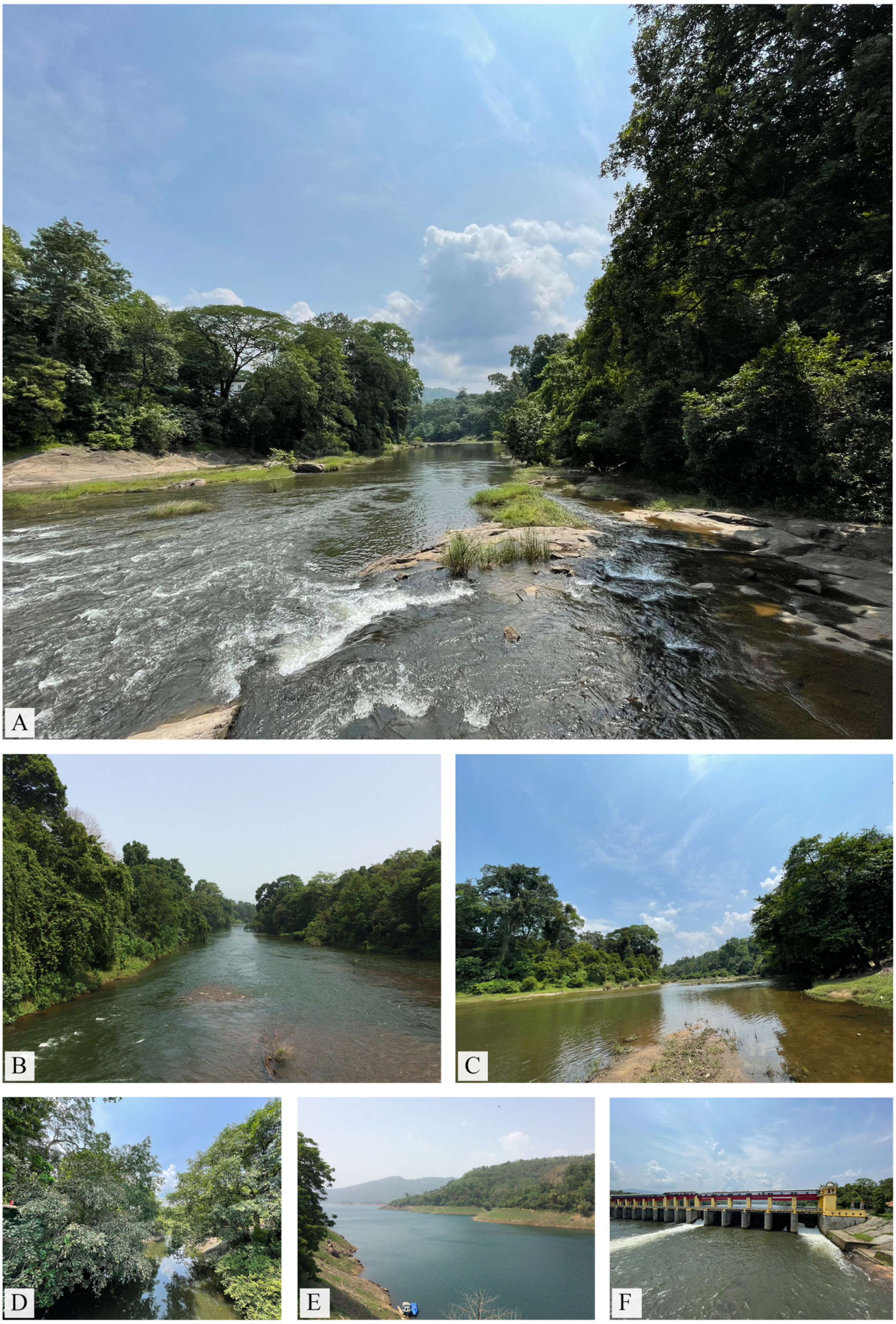


Fig. 1.15. Periyar basin within the Anamalai landscape: A. Pooyamkutty River; B. Idamalayar River; C. Confluence point of Pooyamkutty and Pichi Ar tributaries of the Periyar River; D. Kuttampuzha; E. Idamalayar reservoir; F. Boothathankettu barrage.

Fig. 1.16. Karuvannur basin within the Anamalai landscape: A. Chimmony River; B. Mupli River; C. Chimmony dam; D. Downstream to Chimmony dam; E. & F. Rubber plantations in the riparian zones of the Karuvannur basin.

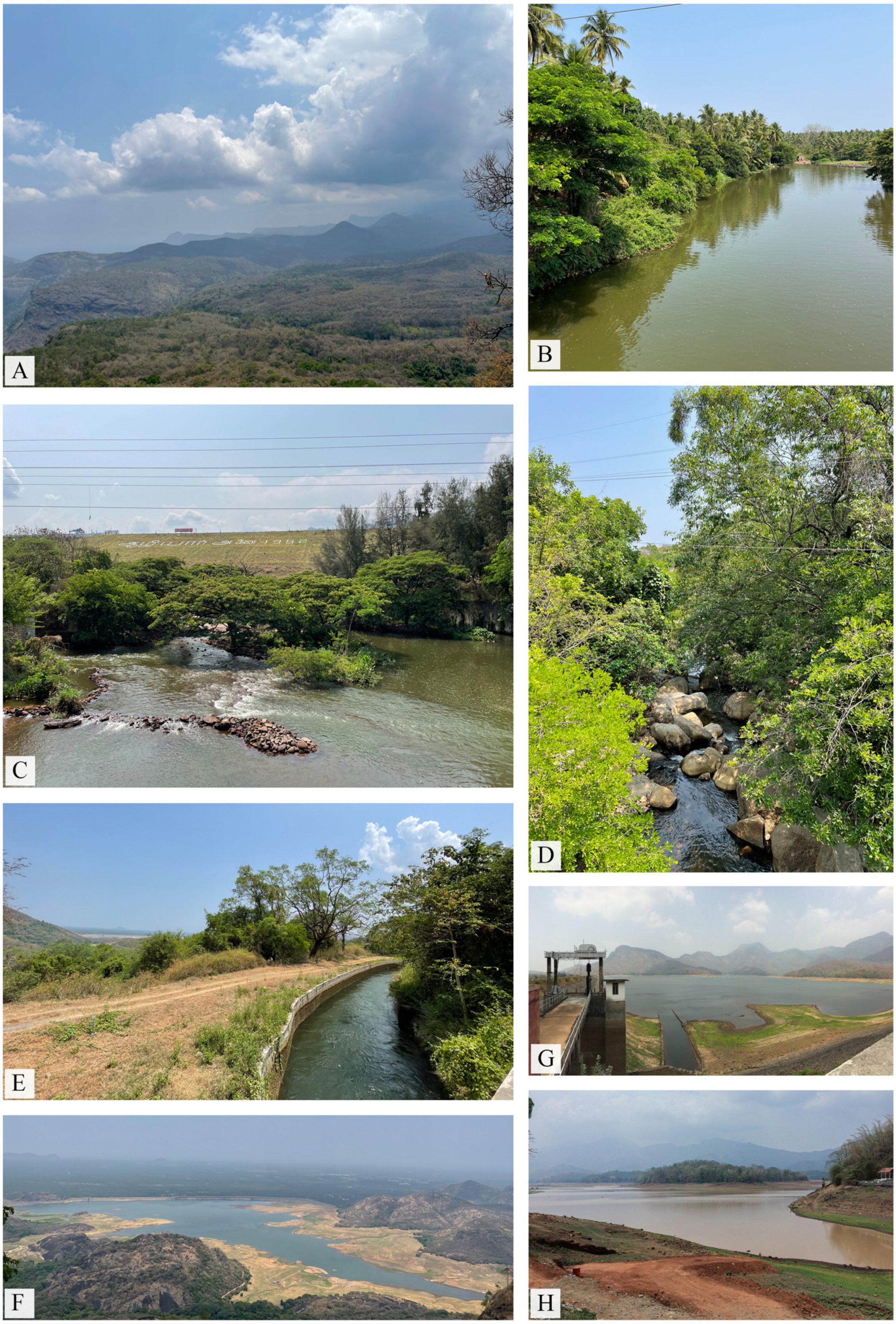


Fig. 1.17. Bharathapuzha basin within the Anamalai landscape: A. Aliyar valley; B. Aliyar River; C. Downstream areas of Aliyar reservoir; D. Perennial stream of Aliyar basin; E. Contour canal near Attakatty; F. Lower Aliyar dam; G. Pothundi dam; H. Mangalam dam.

Fig. 1.18. Pambar basin within the Anamalai landscape: A. Chinnar valley; B. Pambar River; C. Catchments of Pambar River; D. Chinnar River; E. Kootar.

Fig. 1.19. Kechery basin within the Anamalai landscape: A. Riparian zone of the Kechery River; B. Vazhani dam; C. Kechery River downstream to Vazhani dam. D. Spillway of Vazhani dam.

1.5. Plan of the thesis

The thesis is divided into seven chapters covering an introduction, a review of the literature, study results and discussion, a brief summary and recommendations of the thesis. These address all aspects of the work carried out based on approved synopsis. These include collection and interpretation of meteorological data across the Anamalai landscape unit, delineation and mapping of the bioclimate, preparation of riparian forest maps for each river basin and bioclimate within the Anamalai landscape, analysis of phytosociological data gathered through stratified sampling of the riparian zones and evaluation of heterogenic riparian community composition and its classification.

The 1st chapter of the thesis offers a general introduction to the thesis and gives a detailed explanation of the study area. The 2nd chapter, titled "Literature Review," provides a preface on the literature of significant works of prior researchers covering relevant study topics. A description of the bioclimate of the Anamalai landscape based on the meteorological data and its mapping is provided in Chapter 3 as per the first objective. Mapping of the riparian forest and its outcomes are addressed in Chapter 4. Chapter 5 focuses on phytosociological sampling and its analysis to understand the heterogenic plant community composition of the riparian forest within the landscape and its classification. Each chapter begins with an introduction, followed by descriptions of the methods employed, results, discussions, and a concise summary and conclusion. The thesis has a general summary and conclusion derived from the current investigations. This is followed by recommendations evolved from this work. The thesis ends with a detailed reference and appendices. Appendix I to III deals with the details of meteorological data and bioclimatic analysis of Chapter 3. Appendix IV to X contains data on phytosociological sampling and analysis of Chapter 5.

Chapter - 2

Chapter – 2

REVIEW OF LITERATURE

The unique and endangered riparian forests maintain the interdependent ecological balance of flora and fauna in the riparian zone. It carries out a diverse role to maintain riparian zones in a state of balance. As a result, it offers access to various research works to determine biodiversity richness, complexity, bioclimatic influences, patterns of species distribution, vegetation dynamics, flow patterns, flood influence, threat factors and so on. India is a megadiverse country with ecologically rich centres such as the Western Ghats, Eastern Ghats, and the Himalayan region, which contribute to this richness, and they act as the origin of various rivers flowing through variable biogeographic zones. The 44 rivers that travel through Kerala support a diverse array of flora and wildlife, and six of their basin areas are part of the Anamalai landscape studied in detail in this study.

2.1. Bioclimate and riparian vegetation mapping

2.1.a. Climatic zones and vegetation

Alexander von Humboldt (1769 - 1859) was the pioneer in recognising the patterns of distribution of plants and animals and interpreted that climate regulates the distribution of vegetation, with forests serving as the natural climatic climax (Pausas & Bond, 2018). The ancient Greeks were the first to establish global climatic classifications (Sanderson, 1999). Gaussen (1921) investigated the relationship between summer precipitation and the distribution of Mediterranean vegetation. Earlier attempts of climatic classification have been made by Koppen (1900), Thornthwaite (1931, 1948), Holdridge (1967), and Garcia (1973). The Koppen-Geiger system classifies climate into five global climatic zones and 30 sub-classes based on observed vegetation patterns, and it is the most widely applied method for determining climatic zones (Koppen, 1936) and concluded that climate controls the distribution of vegetation (Koppen, 1884). Bagnouls and Gaussen (1957) developed a global climate categorisation based on annual precipitation and temperature regimes, considering the monthly mean of such variables and the duration of cold and warm, dry and humid periods. The relationship between climate, vegetation cover and vegetation distribution has been proven by the studies of Creutzburg (1950), Whittaker (1975), Whittaker (1978) and Woodward (1987).

Connections between the thermal climate and the vegetation zones in China developed by Fang and Yoda (1990). Following this, several investigations on categorising climates were carried out: DeGaetano and Schulman (1990), using principal component analysis and cluster analysis, the USA and Canada's agricultural climates were categorised based on the parameters maximum temperature, minimum temperature, relative humidity, wind speed, number of sunny hours, and precipitation; Malmgren and Winter (1999) analysed Puerto Rico's climate zones using the principal component analysis with distinct vegetal coverings four climatic areas were identified; Ahmed (1997) categorised Saudi Arabia's climate, and nine distinct climate zones were identified. The relationship between climate and how it affects vegetation was studied by Blasi et al. (1999). Unal et al. (2003) cluster analysis was used to identify the different climatic zones in Turkey, and seven unique climatic zones were identified. Yanling et al. (2007) created a map based on the distribution of vegetation zones in China and provided a new approach to vegetation climate classification in China using C-coefficient. Liu et al. (2023) utilised Net Primary Production (NPP) values as the vegetation change index of interest to examine the effects of drought and climatic conditions on vegetation dynamics in Central Asia.

2.1.b. Bioclimate and vegetation types

Bioclimatology is focused on the regional scale relationship between the climate and vegetation. As mentioned above, the Russian botanist Koppen (1900) established one of the first approaches to the study of bioclimatology and published a climatic classification system (Koppen, 1918; Koppen, 1936). Holdridge (1947) developed a life zone concept based on a three-dimensional bioclimate classification that considers biotemperature, precipitation, and an aridity index. Earlier studies of the effects of the climate on vegetation were demonstrated using fundamental climatic features, although the results were not always evident; hence, they were replaced by bioclimatic indices, which emphasise the impact of climate on the growth and dispersion of vegetation and are based on relationships between basic climatic parameters. Elvebakk (1999) proposed that the Arctic can be divided into three bioclimatic zones: the Northern Arctic Tundra Zone (NATZ), the Middle Arctic Tundra Zone (MATZ) and the Arctic Polar Desert Zone (APDZ). The

"Worldwide Bioclimatic Classification System" (WBCS) by Rivas-Matinez et al. (1999) is most widely utilised for categorising natural vegetation based on the response to climate and enhanced by Rivas-Martinez (2005, 2011). It comprises of macro bioclimate, bioclimate, bioclimatic variant, thermotype, and ombrotype units, which is widely applied in many studies (Gonzalez, 2005; Krestov & Mikhailo, 2007; Peinado et al., 2008; Pesaresi et al., 2014; Vladut et al., 2017; Pesaresi et al., 2017; Rivas-Martinez et al., 2017; Souddi & Ghezlaoui, 2021; Pham et al., 2023). The Dynamic global vegetation models have been supported by classifications of bioclimate (Prentice et al., 1992; Sitch et al., 2003). Many studies have attempted to map the identified bioclimates, including a bioclimatic map for Southern Morocco (Oldeland et al., 2008), a bioclimatic map of Portugal (Mesquita & Sousa, 2009), and a bioclimatic map of Tay Nguyen (Van et al., 2014). Gopar-Merino (2015) introduced bioclimatic mapping as a novel technique to evaluate climatic change and its consequences.

The majority of climatological investigations heavily rely on the World Clim global climate dataset (Hijmans et al., 2005) due to its highest spatial resolution (30 arcsec). These climatic classification models and bioclimate indicators were used in modelling the distributions of terrestrial ecosystems (Sayre et al., 2009) as well as for the analysis of climate change impacts on vegetation (Berry et al., 2002; Sitch et al., 2003; Rehfeldt et al., 2003; Thuiller et al., 2005; Ohlemuller et al., 2006; Garzon et al., 2008; Roberts & Hamann, 2012). Bioclimates and vegetation in Northwestern Mexico's Pacific basin studied by Peinado et al. (2011) and Entrocassi et al. (2020) investigated the vegetation and bioclimate of the Subtropical Mountain forests of Las Yungas in Switzerland. Peinado et al. (2018) provided a bioclimatic categorisation of US vegetation. Based on a set of bioclimatic parameters and their associated vegetation structure and ecological functions, Navarro and Molina (2021) proposed a thorough and hierarchical categorisation approach and nomenclature to designate biomes. Effects of bioclimatic index, temporal, spatial, and elevational variations on the Normalised Difference Vegetation Index (NDVI) of various vegetation types given by Gong et al. (2023). The variability and trends of 11 bioclimatic variables have been studied in Finland by Aalto et al. (2023). To gather references about bioclimatic characteristics, a global CHELSA model was also employed by Bocharnikov (2023).

2.1.c. Bioclimate and riparian vegetation

The available research on bioclimate did not pay adequate attention to the distribution of the riparian vegetation. Martnez (1996) classified the lower Caura River's bioclimate as dry tropical forest and the middle and upper Caura River's bioclimate as humid tropical rainforest. As indicated by Chen et al. (1999), riparian vegetation has a significant influence on the local microclimate. The study by Olson et al. (2007) shows that the stream microclimate influences can partially offset the edge effects caused by upslope forest disturbances; thus, properly managed riparian buffers can preserve the suitable microclimates in the riparian zone. Mosner et al. (2015) studied climate change and its effect on vegetation in floodplains, and the study by Fernandes et al. (2016) concentrated on Riparian responses to adverse climate and land use modification. Fernandez et al. (2018) used an advanced bio-hydromorphodynamic model to examine the lower course of the Curueo River in northwest Spain; modelling results show that riparian vegetation and channel morphology will both be impacted by climate change as it relates to mortality, age distribution, and cover and Channel narrowing is assumed to be encouraged by reciprocal interactions between flow conditions and riparian species as biological engineers, which become more prominent as dryness rises. Younger vegetation is also more vulnerable to uprooting and floods due to climate change. Baattrup-Pedersen et al. (2018) documented structural and functional responses of plant communities to climate change-mediated modification in the hydrology of riparian habitats in temperate Europe. Wetlands can be used as an adaptation measure to combat the urban heat island effect by changing them into an urban cooling island (UCI) that contributes to a beneficial urban bioclimate (Shahjahan, 2020). According to Srivastava et al. (2022), Due to orographic lifting mechanisms, topography affects the intensity and geographical distribution of precipitation, affecting the dominant climate and vegetation dispersion.

In India, Champion and Seth (1968) classified the country's vegetation types based on climatic factors and Meher-Homji (1984) identified 14 phytogeographic zones based on bio-climatic factors. Pandey and Gupta (1991) used the monthly temperature and Thomthwaites water balance technique to analyse the agroclimatic features of some districts of Gujarat. A climatic classification for India which satisfactorily explains vegetation types first provided by Mehr-Homji (2001) emphasised the significance of a bioclimatic classification to explain the distribution of species and vegetation and worked on variables length of the dry season, the frequency of rains, and the amount of rainfall that led to the creation of an index of aridity-humidity and the concept of a probable year and discovered a connection between the forest cover and the pattern of rainfall. Bachan (2010) gave a bioclimatic classification of riparian vegetation of the Chalakudy basin. Except for the studies by Bachan (2010) and Bachan et al. (2014), both dealing with the bioclimate of the Chalakudy River basin's riparian vegetation, from the Indian region, no significant research on bioclimate and riparian aspects has been carried out yet.

2.1.d. Vegetation mapping techniques

Vegetation mapping is essential for natural resource management and land use planning since vegetation is the foundation for all living organisms and plays a critical role in global dynamics (Kuchler, 1988). Predictive vegetation mapping and geographic modelling of biospatial patterns in response to environmental gradients were published by Franklin (1995). Bredenkamp et al. (1998) discussed about vegetation mapping, theory, methodology and case studies. Several studies utilised Normalised Difference Vegetation Index (NDVI), Space-borne imaging sensors and remote sensing techniques for monitoring, mapping and the classification of different landscapes (Clark et al., 1985; Elmore et al., 2000; Thenkabail et al., 2004; Geerken et al., 2005; Hansen et al., 2008; Wood et al., 2012; Laurin et al., 2016; De Souza et al., 2019; Neyns & Canters, 2022; Zhou et al., 2023).

2.1.e. Riparian vegetation mapping techniques

Extensive studies on the mapping of forests are done throughout the globe, but riparian forests have received very little attention. Earlier attempts were made by Roberts et al. (1977) to survey the riparian vegetation of California's riparian forests; Bonner (1981) Northeastern California riparian vegetation mapping using high altitude colour infrared aerial photography; Linden and Concannon (1981) utilised digitalised large-scale colour infrared aerial images for mapping riparian vegetation across Southeast Oregon; Bonner and Katibah (1981) used small-scale aerial images to map the riparian vegetation in California; Katibah et al. (1983) aerial photographs were utilised to create maps of different groups of riparian vegetation and their geographic distribution in the Central valley riparian forests of California. Using aerial images of the Central Valley's depositional flatland, maps of riparian vegetation groups and their geographic distribution were generated by Nelson and Nelson (1984). Delong and Brusven (1991) examined the riparian habitat categorisation and spatial mapping in Tom Beall Creek, USA. Using aerial photos, Geographical Information System (GIS) and Arc/Info software riparian vegetation mapping was done by Wilson (1993) for the Trinity River, US. Maps depicting the current land/water cover and areas of the river channel that are vulnerable to vegetation expansion were created by Johnson et al. (1995) using GIS by digitising the colour infrared images for the Snake River, Idaho reach, at a scale of 1:7920. Franklin (1996) used airborne digital multispectral videography and image processing to map the riparian vegetation in the Sierra Nevada. Aerial photographs will continue to be the best method for in-depth analysis of riparian vegetation, according to Muller (1997) in his work mapping riparian vegetation along rivers, which discusses old ideas and new approaches to riparian vegetation mapping. Using Landsat TM imagery, Leon Creek's riparian vegetation was assessed by Cummins (2000). According to Mathooko and Kariuki (2000), mapping and assessment of riparian vegetation species diversity is vital for knowing the diversity of plant species in different periods and locations.

For the Blue Canyon stretch, Hopi Reservation, Arizona, a supervised landcover classification and a vegetation map were created using colour infrared photography and aerial ATLAS imagery by Weber and Dunno (2001). Using space-borne SAR data, Bourgeau-Chavez et al. (2001) delineated the wetlands in Virginia's riparian habitats. Analysis and mapping of the changes to the Lockyer Valley catchment's riparian landscape structure done by Apan et al. (2002). Congalton et al. (2002) point out that riparian vegetation is quite diverse and is arranged in a linear pattern, which poses categorisation issues and renders Landsat TM images inappropriate for use to draft policies and make decisions. Season of data collection does not appear to impact classification accuracy for the riparian vegetation units; in contrast, data collected in direct sunlight had greater overall accuracy than data collected in cloudy conditions (Davis et al., 2002). Data from

NASA's Advanced Visible Infrared Imaging Spectrometer (AVIRIS) at low altitudes and high spatial resolution are being used to map the invasive and associated riparian vegetation by Di-Pietro et al. (2002). Apan et al. (2002) mapped the changes to the Lockyer Valley catchment's riparian landscape structure in Australia. Mapping of the Sacramento River's riparian landscape modification in California, USA by Greco and Plant (2003). Different studies mentioned that Riparian vegetation's complexity and narrow distribution cause difficulties in observing riparian vegetation in low-resolution satellite images (Naiman et al., 2005; Johansen et al., 2010).

Pala (2005) used Digital Orthophoto Quarter Quadrangles (DOQQs) produced by the National Aerial Photography Program (NAPP) to map and identify riparian zone vegetation along streams in the Neuse River Basin of Eastern North Carolina. Using Landsat ETM1 images, Baker et al. (2006) mapped wetlands and riparian habitats in the Gallatin Valley in southwest Montana, USA. Yang (2007) studied the use of remote sensing and geographic information systems to map and define riparian vegetation. Using airborne multi-spectral digital images, the middle of riparian vegetation of the Rio Grande River in New Mexico was mapped by Akasheh et al. (2008). The mapping of riparian vegetation in New Zealand using 73 satellite images was done by Ashraf et al. (2010). Due to their small width, dendritic structure, and the sensitivity of plant species to minute changes in topography that are difficult to reflect by coarse-scale Digital Elevation Models (DEMs), riparian habitats provide several challenges for vegetation modelling; in consideration of this, Dilts et al. (2010) Lidar data was used for mapping the riparian vegetation. Rosati et al. (2012) did a phytogeological investigation and mapping of riparian vegetation in Cilento National Park. Villarreal et al. (2012) introduced regression tree models and post-classification change metrics for mapping and monitoring riparian vegetation distribution, structure, and composition. Riparian wetland ecosystem's plant communities have also been mapped by analysing the aerial images (Kollar et al., 2013). According to Weissteiner et al. (2016), Europe's riparian area represented only 0.95 % to 1.19 % of its total area. De Sosa Miralles et al. (2017) did the riparian zone delineation and mapping in the Conwy watershed in North Wales, UK.

Mapping vegetation using geographic information systems is a widely accepted practice. It is closely linked to remote sensing, digital surveying, mapping, and traditional mapping techniques used to map riparian vegetation (Bareth & Waldhoff, 2018). Using Google Earth images, Song et al. (2018) mapped the vegetation in the Lake Tana region in Ethiopia. McGwire (2019) discusses using the Landsat Normalised Difference Vegetation Index (NDVI) to map riparian vegetation in semi-arid to arid situations. According to the results of the review done by Huylenbroeck et al. (2020), based on the literature from 1980 to 2018 reveals that remote sensing predominated in riparian vegetation studies (428 studies - 89%), modelling approaches (220 studies), and despite the emergence of remote sensing 219 studies were based on fieldwork.

A framework for mapping forest vegetation in riparian zones is presented by Furuya et al. (2020), which hangs on machine learning models and uses orbital multispectral data and Sentinel-2 imagery. Kostianoy et al. (2020) used Google Earth to map Montenegro's intermittent rivers. Daryaei et al. (2021) utilised Sentinel-2 Multi-Temporal Imagery and Pixel-object-based classification to map vegetation in riparian areas. Based on multispectral images from an Unmanned Aerial System (UAS), Rommel et al. (2022) present a machine-learning classification methodology to map basic surface types (BA), Dominant stands (DO), Vegetation units (VE) and Substrate types (SU). Eskandari and Pourghasemi (2022) mapped the distribution, extent, and density of riparian forests in Southern Iran with Sentinel-2A, Google Earth, and field data. Jin and Tai (2023) characterised the changes in riparian vegetation over many decades at several aquatic locations operated by the US National Ecological Observatory Network (NEON). It uses lidar and high-resolution hyperspectral data acquired by NEON's aerial observational platform (AOP) surveys. Recent studies depend on a novel method utilising Google Earth Engine, a platform based on cloud-based remote sensing and geospatial analytical techniques, to quantify changes in river channel position and nearby riparian vegetation area (Pu et al., 2021; Chaulagain et al., 2023).

2.1.f. Indian studies on vegetation mapping

Many studies have been done in India utilising GIS and remote sensing to map and evaluate forest vegetation. India's forest types were first depicted on a map by Champion (1936) and then revised by Champion and Seth (1968). This 1:14,000,000 scale map significantly contributes to the spatial distribution of the various vegetation types in India. An in-depth discussion on using remote sensing and aerial photography was given in the study by Singh (1970). Following these studies the forest map of Peninsular India was prepared by Meher- Homji (1978) at a scale of 1,000,000. Other important research includes use of aerial images for vegetation mapping (Menon, 1988; Roy et al., 1991), changes in forest cover using satellite remote sensing techniques (Madhavanunni et al., 1986; Roy et al., 1993), forest types mapping using Landsat TM FCe, land cover mapping of Chimmony Wildlife Sanctuary, Kerala by Suraj et al. (1996), Mapping of shola grasslands of Eravikulam National Park by Sureshbabu et al. (1997). Application of GIS tools to locate biodiversity hotspots and to map the canopy cover (Prasad et al., 1998; Krishna et al., 2001); Balaguru et al. (2003) used remote sensing and GIS to map the vegetation of the Shervaryan Hills in the Eastern Ghats; Singh et al. (2004) utilised satellite remote sensing to assess and monitor Goa's estuary mangrove ecosystems and also in the vegetation cover mapping and classification of forest types of India (Joshi et al., 2006; Reddy et al., 2015). Using Sentinel-2 and SAR Sentinel-1 satellite data, Erinjery et al. (2018) mapped the different vegetation types found in the tropical rainforests of the Western Ghats. Das and Singh (2013) mapped forest types in Maharashtra's Western Ghats region using Landsat TM. Similarly, Parida and Kumar (2020) mapped mangrove forests along the Odisha Coast using Landsat-5 and sentinel-2 satellites. Images from Google Earth were used for mangrove species identification in Malad Creek, Mumbai, by Nagarajan et al. (2022). Karsch et al. (2023) used Landsat 8 and Google Earth Engine to analyse changes in mangrove vegetation cover in the Indian Sundarbans National Park.

Less studies have been done on mapping vegetation along the riparian system of Indian rivers, especially those originating in the Western Ghats, and most mapping studies in India are focused on the major forest types. Madhavanunni et al. (1985) created a map of the forest cover of the Godavari basin using 1:25,000-scale aerial photographs. Murthy and Rao (1997), a temporal analysis of land use and land cover were conducted in the Varaha River basin of Andhra Pradesh province of India, using remote sensing based on the data from 1986 and 1992. The land use patterns, vegetation properties, and disturbances in the river margins were identified using GIS mapping of the riparian vegetation in the middle and lower zones of the Chalakudy River basin (Bachan, 2003), which is the first attempt to map riparian vegetation from Kerala. The Pamba River's disturbed areas and the distribution of endemic, invasive, and endangered riparian species were mapped using ArcGIS 9.3 software by Joby (2012). GIS technology was used to create the entire river basin map of Chalakudy by Bachan et al. (2014). ARC GIS software was also used by Jisha (2020) to analyse the riparian vegetation, land use patterns, and disturbance regime of the Thuthapuzha sub-basin, a tributary of Bharathapuzha.

All these studies make it clear that the narrow width and topography of the Riparian forests act as a challenge for field-based mapping techniques in the riparian zones and are more time-consuming. Thus, new practices combined with field verification surveys are the best way to carry out riparian vegetation mapping with the highest level of accuracy.

2.2. Riparian vegetation composition and classification

2.2.a. Plant communities and vegetation assessments

The book Research Methods in Ecology, published by Clements (1905), is a pioneering work on ecology. Gleason (1926) proposed the concept of plant associations, which rely on the coincidence of migration and environmental selection across a region, theories of Climaxes (Clements, 1928; Clements, 1936; Tansley, 1939; Whittaker, 1951; Whittaker, 1953) and continuum concept by Gleason (1939) form the fundamental ideologies of plant communities and vegetation dynamics. One of the earlier works that describes the vegetation of Burma was done by Stamp (1925). Also, the community co-efficient concept and the relation between the number of species with area by Jaccard (1912), the publications of Clements (1916), Tansley (1926), and Odum (1979) contribute towards illustrating the processes of vegetation succession and climax. Whitmore (1975) and Good (1964) both made significant contributions to the study of tropical vegetation.

With the development of quantitative sampling techniques (Pound & Clements, 1898), application of the Quadrat methods (Gleason, 1920), frequency analysis (Raunkiaer, 1934), various methodologies for vegetation analysis by Weaver and Clements (1938) and Daubenmire (1959), Diversity indices (Simpson, 1949; Shannon & Weaner, 1963), the species-area curve approach to standardise quadrat sizes in sampling regions (Cain, 1938; Curtis & Mclntosh, 1951), multidimensional ordination methods by Bray and Curtis (1957), basal area as dominance index (Curtis, 1959), concepts of density, frequency, abundance, and the importance value index (Phillip, 1959; Curtis, 1959; Muller-Dombois & Ellenberg, 1974) and the species richness (Magurran, 1988) are the key contributions to the field of plant communities and vegetation dynamics that have enhanced the understanding of vegetation of an area.

2.2.b. Riparian plant communities and riparian vegetation studies

Significant steps to study riparian vegetation are marked by the earlier work of Simpson (1975) examined the vegetation around the Chobe River in southeast Botswana; Rucks (1984) studied the composition and trend of the riparian vegetation along five perennial streams in southeast Arizona. Then Shah et al. (1985) studied the significance of riparian vegetation in Pakistan; Ericsson and Schimpf (1986) studied woody vegetation along the lower zones of the Sucker River, which are the pioneering approaches to the study of riparian vegetation. The riparian vegetation along the river Adour in southwest France is subjected to the continuity/discontinuity concept to properly identify the longitudinal structure and measure the floristic continuity of the fluvial axis (Tabacchi et al., 1990).

Both stream and riparian zone processes are significantly influenced by riparian vegetation (Gregory et al., 1991). Edge sites are more diversified and have higher stem and sapling numbers than floodplain interior sites, according to Kupfer and Malanson (1993). Naiman et al. (1993) identified that compared to nearby upland ecosystems, riparian zones have a more significant number of species. Malanson (1993) described the riparian landscapes in detail. Decamps and Tabacchi (1994) used samples from North Sweden and South France to demonstrate the diversity of vegetation along river margins. Nilsson et al. (1994), by comparing the Vindel River's main channel and seven of its tributaries, show that the main river exhibited a high species diversity at intermediate altitudes and strong correlations were found between community type and altitude, height and distance from the active channel, floor width of the valley, fluvial landform, and the soil texture. Kittel (1994) proved that the species diversity and plant structure varied within a single length of the river with height and distance from the active channel, which were connected with sediment size. Major riparian plant species in Eastern Wyoming delineated by Jones and Walford (1995). Busch and Smith (1995) explained the mechanisms behind the loss of woody species in southwestern US riparian environments. Smith et al. (1995) described woody riparian vegetation structure and composition in Great Basin National Park, Eastern Nevada.

The physical structure of riparian corridors and intermediate disturbance regimes were primarily responsible for the invasibility of riparian plant communities (Tabacchi et al., 1996). Stromberg et al. (1996) state that riparian vegetation in semiarid locations is affected by the reduction of groundwater. Naiman and Decamps (1997) explain that the fluvial corridor's upland impacts, geographical channel dynamics, altitudinal climatic variations, and changing flood regimes are connected to the biological diversity of the riparian zone, and the ensuing dynamic ecosystem supports a diversity of life history strategies, biogeochemical cycles and species adapted to disturbance regimes over large geographical and temporal dimensions. Riparian forest structure and composition with particular emphasis on the geomorphic site conditions in Northern Japan, along the Tokachi River, given by Nakamura et al. (1997). Williams and Moriarity (1998) surveyed four minor streams of riparian vegetation in northwest Pennsylvania. According to Pollock et al. (1998), higher riparian plant species richness is related to the diversity of microhabitats. Primack (2000) studied the impacts of climate change on the Pere Marquette River riparian vegetation in Michigan. Many riparian-related research works focus on the riparian zone herbaceous floristic diversity (Raghubanshi, 2001; Srivastava, 2003; Srivastava, 2006). Hibbs and Bower (2001) show that site conditions and competition influence tree regeneration in the riparian zone. Qing-chun et al. (2002) compared riparian and non-riparian forests and found that the riparian zone had higher species richness, Shannon-Weiner index, and Species evenness. Nilsson et al. (2002) imply a functional connection between channel features, plant community composition, and dispersion attributes.

Four hundred and forty-five (445) plant species and 98 vegetation types were documented from 347 sampling plots in the Columbia River basin by Crawford (2003). Among them, most of the species are native shrub species. Daley and Kirkpatrick (2004) identified, mapped, and described twenty-one riparian plant communities. Coles-Ritchie (2005) asserts that to more precisely define and monitor changes in riparian vegetation and related ecological services, it is necessary to either develop new data collection and summarisation techniques or enhance the repeatability of existing ones. Fierke and Kauffman (2005) studied riparian forest structural dynamics along a black cottonwood successional gradient in the Willamette River. Balian and Naiman (2005) studied the abundance and development of riparian trees in the Washington lowland floodplain of the Queets River. Veneklaas et al. (2005) studied the riparian forest composition for 80 plots in the Yucao River watershed (2550 km^2), a tributary of the Meta River in eastern Colombia, and identified 147 tree species from 3.2 ha area.

Findings of the study by Pettit and Naiman (2006) show that after a severe flood, large woody debris (LWD) forms in heterogeneous patches that will influence the post-disturbance recovery of riparian vegetation by creating a range of niches for seedling establishment. The study suspects that high moisture content, especially during the dry season, nutrients, as well as protection from seasonal floods and herbivory, are the main factors contributing to improved seedling survival in LWD. The distribution of species in the woody riparian flora of Western Oregon exhibited high correlations with climate factors, which served as the main predictors of compositional change across riparian sites, which is examined by Sarr and Hibbs (2007), measures of topography and disturbance also explained further local variation in composition.

One hundred and ninety-six (196) species from 139 genera and 51 families were identified by Sambare et al. (2011) from riparian forests along four types of watercourses in Burkina Faso. Dybkjaer (2012) established a correlation between the number of plant community types in the riparian regions and stream mean depth as a measure of stream size. Tererai et al. (2013) analysed variations in floristic diversity, stand structure, and resident species composition driven by the invasion of *Eucalyptus camaldulensis* in riparian zones of the Western Cape, South Africa, showed that native species' structural characteristics, species richness, and diversity consistently declined throughout the invasion gradient. Meek et al. (2013) identified ten different plant communities; some are unique and predominated by alien plant species from the Eerste River, Western Cape of South Africa. Many rivers in America, Europe, Africa, and Australia have been the subject of studies on the species richness, diversity, and phytosociology of riparian zones, but few riparian related studies reported from Asian rivers (Joby, 2012).

On small-order streams, plant communities differ along wet-to-dry hydrologic gradients, and the findings of Reynolds and Shafroth (2017) show that under drying circumstances, the species richness and cover of annual plants will rise while those of the total, perennial, wetland, and native plant groups will decline. With 68 families and 261 plant species, the Wami River in Tanzania has a Shannon diversity index that ranges from 1.63 to 2.94 and shows a sharply diminishing trend towards downstream (Mligo, 2017). Meragiaw et al. (2018) documented that Walga's riparian vegetation had 99 woody vascular plant species belonging to 81 genera and 45 families with four main plant community types. Only 10% of the species were unique to the region. High levels of litter and facultative wet species were linked to the most stable stream types, lower Bank Erosion Hazard Index (BEHI) scores, and stable bank height ratios. In contrast, bare ground and early successional species were connected to unstable channels. The most effective protection for intermittent streambanks was derived from late-successional facultative wetland plants (Hecker et al., 2019). A review by Dufour et al. (2019) found that there is no single, well-defined scientific community that specialises in riparian vegetation. Park and Kim (2020) indicate that the interaction of the hydrological regime, the physicochemical makeup of the soil, the intrinsic traits of the species, and interspecific competition results in the formation of the vegetation structure in the riparian zones. Zeng et al. (2020) identified that high soil moisture and soil salinity, low groundwater salinity, and shallow groundwater depth were linked to greater plant diversity.

To discriminate between riparian and upland vegetation and to evaluate the connectivity of riparian vegetation patches, researchers used the Normalised Difference Vegetation Index (Manning et al., 2020). Rahim et al. (2021) revealed that the distribution of plant patterns was mainly connected with soil properties, altitudinal gradient, slope steepness, and slope exposure. A clustering analysis by Fogliata et al. (2021) found five distinct plant communities with distinctive ecological characteristics from an ecological analysis of the riparian ecosystem of the Lombardy region of North Italy. In the Barumun Watershed, 51 plant species were recorded, of which 37 were discovered in the Barumun River, 20 in the Tasik Rivulet, and 17 in the Titi Kembar Rivulet. The number of tree species was 22 (43.13%), followed by 22 species of herbs, 3 species of climbers, 2 species of shrubs, and 2 species of palms (3.92%) (Rambey et al., 2021). Jamtsho et al. (2021) investigated the diversity, distribution, and ethnobotanical use of riparian plant species along the Sherichhu River in Eastern Bhutan. Yang et al. (2022) studied riparian plant's responses to edaphic factors of the Hanjiang River in China. Environmental and spatial variables drive the compositions of the riparian plant communities in the upper Han River basin also environmental filtration was found more significant in explaining species composition than spatial variables (Fu et al., 2022).

A study by Fashae et al. (2022) shows that the variance in species composition throughout the river orders shows that the first-order streams contain the greatest diversity of taxa. In first-order streams, there is not much ecological degradation. However, as order rises, there is more ecological degradation, and the study concludes that higher-order rivers often have low levels of biodiversity and ecological value, which results in relatively poor health, especially under conditions of intense anthropogenic pressure. According to Figueiredo et al. (2022), the edaphic parameters were related to the similar species composition and diversity among the sampled area. Study results of Wang et al. (2022) aid in comprehending the forest structures in riparian habitats and helping to understand how plants and animals have evolved together (Plant–Bird coevolution). Brown et al. (2022) compared the effect of dam removal on the species diversity of lower zones on the Elwha River, Washington, and proved that huge dams diminish the diversity and richness of native species in the lowest river sections. Deposition brought on by high amounts of discharged reservoir material during dam removal affected it inconsistently, and this diversity can be restored in the future.

In the South Asian area and a few nations throughout the globe, there is a lack of focus on riparian buffer width that has to be shared among all stakeholders

(Majumdar & Avishe, 2023). Burgess et al. (2023) suggest that the success of riparian restoration initiatives is influenced by planting implementation techniques, site-level physical conditions, and time since planting. If these elements are not considered when designing and implementing restoration projects, it may result in a lack of observable response. Variations in groundwater depth have an impact on patterns of species diversity, which are sensitive to richness. In contrast, the level of surface water disturbance impacts patterns of species evenness (Shi et al., 2023).

2.2.c. Indian studies on riparian vegetation composition

Many investigations have documented the floristic diversity of the Anamalai landscape: the flora of Palghat District (Vajravelu, 1990); the flora of Nilambur (Sivarajan & Mathew, 1997); the flora of Thrissur forests (Sasidharan & Sivarajan, 1996); flora of Chinnar Wildlife Sanctuary (Sasidharan, 1999). Other phytosociological investigation records 359 tree species, 25% are endemic species, and 109 species belonging to threatened categories from Parambikulam Wildlife Sanctuary by Sasidharan (2002). In a stratified transect survey in the Indira Gandhi Wild Life Sanctuary forest regions, 169 tree species were identified by Joseph (2009); from the forests of Malayattur, Sakthivel and Sreekumar (2011) documented 385 species of angiosperms and from the six sampling locations of (In 3 ha) Nelliyampathy regions, Ramachandran and Swarupanandan (2013) recorded 152 species of plants representing 120 genera and 51 families. Also, the Biodiversity of the Malayattur forest division was studied by Renuka et al. (2010) and an analysis of the floral diversity of the Kerala region of Southern Western Ghats endemic flowering plants done by Jagadeesan (2019) and so on.

Research on riparian floristic diversity and composition that is pertinent emerged from the Thambirabarani River's riparian vegetation that flows through the Mundanthurai Wildlife Sanctuary of South India, reported 47 tree species, 13 shrubs, and 15 climbers (Johnsingh & Joshua, 1989). One hundred forty-one (141) species of angiosperms from 48 different families and seven species of pteridophytes from seven different families were identified in the Kaziranga National Park, which is situated on the Brahmaputra River's floodplain by Baruah and Baruah (2000). More than 50 different species of angiosperm trees and 12 different species of shrubs were found in the riparian zone of the perennial river system of the Netravati Valley by Korse and Krishnakumar (2006). The condition of the riparian vegetation in response to anthropogenic disturbance in the Cauvery River basin was studied by Sunil et al. (2011). A riparian vegetation survey using quadrats along the Tungabhadra River was done by Kumara and Srikantaswamy (2011) and also in the Khok River of Garhwal Himalaya by Iqbal et al. (2012). Sunil (2012) identified 177 tree species from 80 sampling plots of the Cauvery basin, of which 30 threatened, 32 endemic, and 4 different vegetation types were segregated also noted that the species composition of the riparian zone had changed due to the intense biotic pressure from plantations and other anthropogenic impacts.

Other important phytosociological and floristic studies from the riparian vegetation arise from many rivers: Pambar and Thalaiyar freshwater streams of Tamil Nadu (Packiaraj & Kannan, 2014); the riparian flora of Mahi River in Gujarat, which includes 328 species of flowering plants from 230 genera and 73 families (Sankhwal et al., 2015); Riparian areas along Mini River of Vadodara reported 91 plant species from 79 genera and 36 families (Shah et al., 2015); in the Polavaram dam submergence riparian zone in the Eastern Ghats of Andhra Pradesh, identified 276 angiosperms belonging to 80 families and 223 genera (Rao, 2016); riparian vegetation assessments in the in Dikhu River, Nagaland (Devlin & Singh, 2018); Neeru stream, a tributary to the Chenab basin (Sharma, 2018); Alaknanda and Bhagirathi basin of the Garhwal Himalaya (Dharmaveer, 2019); Over the Amirthi River in Tamil Nadu (Sakthivel et al., 2019); Comprehensive analysis of the flora of the Ganga River (Shruti et al., 2019). The study by Bachan and Devika (2020) in the Chalakudy River basin proved that dam modification and diversion reduced the number of climax species, increased the presence of ruderal species, lowered diversity, and transformed riparian vegetation into secondary degradation types. This is followed by many studies focusing on riparian vegetation composition and richness: Sharma and Sharma (2022) from North-western Himalayan Riparian zone of India; Northern Chhattisgarh's riparian vegetation areas by Kujur et al. (2022); Riparian zones of the Zabarwan mountain range, Kashmir Himalaya by Haq et al. (2023) and along the Tungabhadra River by Siddeshwari & Kotresha (2023).

In Kerala, 329 angiosperms were identified in the riparian vegetation assessment by Bachan (2003) in the Chalakudy River, which included 260 genera and 97 families. Among these, 24 species are endemic to the Western Ghats, and 10 are threatened. There were 130 flowering plants and 20 different types of mangroves in the riparian zone of the Valapattanam River, according to Sreedharan (2005). A detailed riparian floristic study by Bachan (2010) in the Chalakudy River basin identified 696 flowering plants from 450 genera which belong to 129 families, of which 254 are endemic, and 33 are RET species. A study of Alakyam stream's riparian zone by Manoj et al. (2012) recorded a total of 63 species of trees from 37 families. The Pamba River's riparian flora by Joby (2012) revealed that the riparian zone of the Pamba River consists of 545 angiosperms, 3 gymnosperms, and 31 pteridophytes within 119 families. More than 441 species were identified from the riparian vegetation along the Meenachil River basin by Vincy et al. (2014). A study by Cherullipadi & Paul (2016) identified 176 angiosperms in 63 families, 4 pteridophytes, and 1 gymnosperm in the riparian areas of the lower zones of the Bharathapuzha River, and the herbaceous flora consisted of 73 species in 29 families. Jisha et al. (2018), from the Kanjirapuzha basin of Kerala, documented 196 species of flowering plants belonging to 62 families. Sherina et al. (2018) recorded 91 plant species from the riparian zone of the Sokanasini River in Kerala, distributed among 72 genera and 30 families. A total of 1243 species of flowering plants from 150 families were identified in the riparian regions studied by Sabu et al. (2019) by the assessment of the impact of flood and landslides on riparian vegetation in Pamba, Periyar, Chalakudiyar, and Bharathapuzha. Periyar (799 species) has the most species, followed by Pampa (549 species), Chalakudy (470 species), and three tributaries of Bharathapuzha contain 421 species. Herbs make up the majority of the species (47%) and are followed by trees (25%) and shrubs (15%) and climbers (13 %). Floristic analysis conducted in the lower riparian zones of the Chaliyar River, Mohanan et al. (2020) recorded 171 species, and they are categorised into 134 genera and 45 families. Jisha (2020) reveals that the riparian zone of the Thuthapuzha sub-basin of Bharathapuzha is comprised of 612 angiosperms that belong to 402 genera within 116 families, 34 pteridophytes and 2 gymnosperms. According to the assessments by Bachan and Pooja (2017) and based on the criteria for the IUCN endangered ecosystem status assessment by Bachan et al. (2022), the low-elevation tropical evergreen riparian forest of the Western Ghats has been designated as critically endangered. A floristic investigation by Mohanan (2023) revealed 419 angiosperms, 1 gymnosperm 16 pteridophytes from the riparian zones of the Chaliyar River basin.

2.2.d. Pioneers of vegetation classification

The prior vegetation studies include the contributions of Stebbing (1922, 1926) and floristic classification by Clements (1916, 1928), Tansley and Chip (1926), Champion (1936), Chandrasekharan (1962) and Champion and Seth (1968). Among these, the most extensively used system for classifying forests is that of Champion (1936) which is updated by Champion and Seth (1968). The system of life zones, introduced the first by Holdridge (1947), was a pioneer study of the Worldwide Classification System of ecological types predicted from climate. Physiognomic classifications were done by Kuchler (1949) and Webb (1959, 1978). Other significant studies based on physiognomic classifications were done by Gaussen et al. (1961) and Ellenberg and Muller-Dombois (1967). This is followed by the vegetation of the humid tropics and its riparian forests were classified in the physiognomic classification of Fosberg (1967) and Beard (1978). International vegetation categorisation and mapping done by the United Nations Educational, Scientific, and Cultural Organization (UNESCO, 1973). Mueller-Dombois and Ellenberg (1974) created the theoretical framework for classifying vegetation to reduce its complexity. The integration of floristic composition, physiognomy, and environmental factors into the classification of vegetation types was proposed by Westhoff and van der Maarel (1978). Following these, Augiar (1996) provided a preliminary vegetation classification for Portugal, Patten (1998) provided a vegetation classification for North America and vegetation classification for North Western Pennsylvania by Williams and Morarity (1998).

2.2.e. Studies on riparian vegetation classification

Globally, a wide range of studies has already been done on the make-up and classification of riparian vegetation. The earliest classifications of riparian vegetation were developed by Pase and Layser (1977) for the riparian habitat in the Southwest. Classification of wetland and deep water habitats in the United States given by Cowardin et al. (1979) and the wetlands have been described by their plant communities. Different studies made initial approaches for riparian vegetation classification (Johnson et al., 1984; Youngblood, 1985; Stancioff et al., 1985; Kovalchik, 1987; Padgett, 1989; Baker, 1989; Keith et al., 2013). In Chitwan National Park of Nepal, subtropical riverine grassland and woodland were classified by Lehmkuhl (1994). The first classification of Mexico's riparian vegetation was offered by Huerta (1994), and the classification of riparian and wetland areas of Montana was given by Hansen (1995). This is followed by the classification of Southwest Colorado on the Animas River (Walford & Baker, 1995) and the Gunnison River Basin of Colorado (Kittel et al., 1995). Durkin et al. (1996) provided a tentative classification of the riparian/wetland vegetation communities in the New Mexico basin of the Upper and Middle Rio Grande. Kettler and McMullen (1996) gave a classification of riparian vegetation in the Routt National Forest. An initial assessment of the low-elevation riparian vegetation categorisation for the Olympic Experimental State Forest by Chappell (1999) and the riparian plant associations of the Colorado Rio Grande closed basin watersheds were classified by Kittel et al. (1999). Classification of community types, successional sequences in the Copper River delta, Alaska and the application of ecological categorisation in riparian vegetation restoration in Colorado was provided by Boggs (2000) and Kittel and Comer (2004), respectively.

After a research gap between 2005 to 2015, the study by Ahn et al. (2016) identified 22 different plant types and 101 different species from the Damyang riparian wetland. Four recognised vegetation communities were in the Okavango Delta, Botswana, by the findings of Tsheboeng et al. (2016). Studying woody species of riparian vegetation along the Walga River in Southwest Ethiopia by Meragiaw et al. (2018) identified four main plant community categories. Along the Thamalakane River, Northwestern Botswana, five significant forest communities were identified by Tsheboeng et al. (2020). A systematic categorisation of the vegetation found on European mountain river gravel bars was provided by Kalnikova et al. (2020). The latest studies integrating climatic factors with data from the Normalised difference vegetation index (NDVI) and the riparian forest types are classified by unsupervised cluster analysis technique by Xu et al. (2022).

2.2.f. Vegetation classification in India

The first widely accepted comprehensive classic work on the classification of Indian forest types by Champion (1936), revised by Champion and Seth (1968), classified the observed vegetation types of India into five broad vegetation groups: 1. Tropical forest (7 subtypes), 2. Montane subtropical (3 subtypes), 3. Montane temperate (3 subtypes), 4. Sub- Alpine Forests (1 subtype), 5. Alpine Scrub (2 subtypes) and 16 major subtypes based on climate (temperature and rainfall) and length of the dry season and mentioned riparian forests as a vegetation type under Major group I, Moist Tropical Forest subgroup 4 E/RS1- Tropical Riparian Fringing Forest and Major group II, Dry Tropical Forest 5/ISI – Dry Tropical Riverain Forest. Forest types of Kerala were classified by Chandrasekhsran (1962) using a framework developed by Champion (1936), with five major Groups: 1. Tropical Wet Evergreen Forests 2. Tropical Moist Deciduous Forests 3. Tropical Dry Deciduous Forests 4. Montane Sub- Tropical Forests 5. Montane Temperate Forests are all divided into climax secondary and edaphic types where the changes are applied. In India, Meher-Homji (1984) identified 14 phytogeographic zones based on bioclimatic factors. For the Southern Western Ghats region, Nair (1991) detailed the Gadgil and Meher-Homji (1982) and Champion and Seth (1968) classifications and analysed each in depth. Gadgil and Meher-Homji (1982) offered more meteorological and biogeographic information along with more thorough descriptions of the various vegetation types. Meher-Homji (2001) identified 31 major vegetation types for peninsular India and classified them into four broad groupings: 1. Thorny types 2. Deciduous types 3. Semi Evergreen types 4. Evergreen types. Categorisation of the wet evergreen forest types that cover the Southern Western Ghats of India, from the plains to higher elevations, five different types of wet evergreen types have been recognised by Pascal et al. (2004).

Identified bioclimatic differences successfully correlated with heterogeneity in vegetation composition, which clearly defined the reason for differences in vegetation types within the same rainfall and altitudinal regime, including the secondary vegetation or edaphic or seral stages by the studies of Bachan (2010) and Bachan et al. (2014). The presence of a gradient of vegetation composition from pioneering, seral, edaphic and climax stages is unique to a given bioclimate. This can successfully define or fine-tune the classification of vegetation in each bioclimate and that could be identical within similar bioclimate across the latitude. Such an understanding of the bioclimatic heterogeneity and heterogeneity of vegetation composition within was used to understand riparian communities in the Chalakudy river basin, Kerala, and an attempt for a bioclimatic classification in the riparian zones has been pioneered and established by Bachan (2010), Bachan & Pradeep (2010) and Bachan et al. (2014) and identified 18 different riparian vegetation types within four bioclimatic regimes identified through pooling 20 years of rainfall and temperature data contributed towards the development of ecorestoration protocols and ensure the effective implementation of eco-restoration in riparian zones (Bachan, 2018; Bachan & Pooja, 2019). Following this, Bachan and Pooja (2020) made an initial attempt to classify riparian forest types in Kerala as an addition to Champion and Seth's (1968) forest classification, followed by Bachan et al. (2022) and Bachan (2023) provided riparian forest classification for the entire Western Ghats. Hence, the present study will further amplify earlier findings on riparian forests in the Western Ghats.

2.3. Influence of river flow on riparian vegetation

Ewel (1979) states that modifications to the hydroperiod or the magnitude of water level fluctuation cause significant changes in riparian communities. In comparison to still-water wetlands, flowing-water wetlands showed greater rates of gross primary productivity, litterfall, respiration, organic matter export and net biomass production, and this might be because moving water provides less stressful conditions (Brown et al., 1979). Thus, many studies agree that variations in water levels impact wetland and woodland riparian communities (Teskey & Hinckley, 1977; Lee & Hinckley, 1982). According to Stromberg et al. (2005), when considering the ecosystem at larger geographical and temporal dimensions, perennial-flow sites have high abundances of plant functional categories. In the floodplain area next to the river channel, mesic riparian perennials are common, and after large floods, late-summer hydric and mesic annuals are occasionally in higher abundance. And the impact of stream flow patterns on riparian vegetation along a semiarid river was studied by Stromberg et al. (2009). The riparian trees and shrubs responses to flow regulation in a boreal stream of northern Sweden done by

Bejarano et al. (2011). Rivaes et al. (2013) analysed responses of the riparian vegetation to modified flow regimes brought on by climate change in Mediterranean rivers. Modelling of the evolution of riparian woodlands under climate change in three European Rivers with different flow regimes was accomplished by Rivaes et al. (2014), and Vesipa et al. (2017) confirmed that variations in river flow impact the dynamics of riparian vegetation.

2.4. Influence of flood on riparian vegetation

Baker (1990) asserts that regional differences in the diversity of riparian wetlands are connected to the variations in the macroenvironment and flood potential. Massive floods deplete the biomass of trees (Stromberg, 1993). Studies on stream Cheongmi's riparian vegetation by Cho and Cho (2005) show that it sustained its uniqueness due to the repeated yearly flooding disturbances. Wintle and Kirkpatrick (2007) studied the responses of riparian forests and flood, and identified that the regions that experienced flood scour had the most remarkable species richness and diversity. Herb species seem dependent on gaps for colonisation, and some crucial riparian shrub species also need disturbance to sustain their abundance. Regulation of these rivers will reduce the richness of the riparian vegetation downstream of dams because differences in species composition are connected to flood-induced characteristics of the riparian environment. This is also supported by Tsheboeng et al. (2016) that for the Okavango Delta to retain its diverse ecology, it is crucial to preserve the hydrologic condition defined by flood pulses. Jamtsho and Sridith (2017) add that the species composition of the plant communities, topographic features, and environmental factors like litter accumulation and flooding conditions had some influence. Su et al. (2020) clearly explain that prolonged flooding significantly decreased the number of species but had little effect on the riparian vegetation cover. Due to the disappearance of stress-tolerant woody plants and competitive perennial herbs, this unprecedented flooding resulted in a reduction in functional diversity; even under such prolonged hypoxic circumstances, competitive annual herbs and flood-resistant riparian herbs were favoured because they were the most common functional guilds, and compared to non-flooding areas, flooding places had a more considerable diversity of riparian plants (Steinberg et al., 2021).

2.5. Riparian vegetation and disturbance studies

Numerous studies have documented how riparian vegetation changes in response to hydrological alterations (Nilsson et al., 1991; Nilsson & Jansson, 1995; Tabacchi et al., 1996; Toner & Keddy, 1997). Thorne et al. (1997) showed that upland ecosystem disturbances and aquatic system disturbances, such as fire, wind, water flow, debris, lateral channel erosion, and floods, impact riparian forests. However, according to Lamb et al. (2003), the plant communities in the riparian zone are not significantly impacted by upland forest disturbances because the riparian species are acclimated to a high-light habitat and flooding disturbance. Van Coller et al. (1997) noted that in response to situations of geomorphological change brought on by progressive sedimentation, modifications occur in the riparian vegetation composition. In addition to changes in the hydrologic regime, human-induced alterations in the transfer of materials also have an impact on riparian forests. These changes have site-specific ecological effects that are still difficult to anticipate. However, they affect species composition, distribution, soil biogeochemical cycles, and sediment moisture retention (Naiman et al., 1998). Stevens and Cummins (1999) study on the influence of disturbance on stream riparian areas, the main finding was that anthropogenic disturbance compromised the health of the stream environment. Particularly, detrital processing rates were less predictable in agricultural streams than in streams with forests.

Findings of Merritt and Cooper (2000) suggest that the building of the dam causes a deep river channel into a shallow channel, and the replacement of native species that have predominated in riparian areas is one of the long-term consequences of channel and hydrologic modifications. Many studies point out that as a result of dam construction, rivers become fragmented, disrupting natural dispersal patterns and affecting riparian populations, and the altered disturbance regime favours species that are not native, changing the composition and dynamics of the vegetation (Jansson et al., 2000; Andersson et al., 2000; Cowell & Dyer, 2002). Moffatt et al. (2004) examined the riparian forest along the urban to rural disturbance zone of Assiniboine River, Canada, based on differences in the composition and diversity of herbaceous, shrubby, and tree species, and they correlated with the proportion of adjacent land use, size of the forest patch, connectivity, and the area-perimeter ratio and the study results confirm that riparian forests in urban areas were found to be more fragmented and disturbed. Different studies confirm that river regulation seems to reduce the diversity of plant species and make it easier for alien plant species to proliferate (Uowolo et al., 2005; Richardson et al., 2007). Aguiar and Ferreira (2005) found that small-scale human disturbances in riparian corridors contribute significantly to the remaining ecological diversity. According to Blanchard and Holmes (2008), the fell and remove technique is regarded as the most effective technique in supporting indigenous plant regeneration, and it is successful only when combined with ongoing alien follow-up control, which is capable of minimising alien re-invasion of riparian habitats. In the study of Pennington et al. (2010), exotic canopy species rose as urbanisation increases, whereas native canopy and understory species decreased. The impact of human interventions and disturbances over the past decades in the catchment areas are visible in the floristic composition of lower riparian zones of western Greece in the study of Manolaki and Papastergiadou (2012). A low number of considerably smaller riparian tree clusters were observed in the riparian vegetation close to agricultural areas in the study of Fernandes et al. (2011) with less complicated forms and revealed that proximal land use has a greater impact on the structure of riparian vegetation than distant land use. Omelchuk and Prots (2014) observed that in river areas subject to regulation, the proportion of seeds from invasive species rises noticeably and native species are replaced with associations between perennial herbaceous and non-native species. You et al. (2015) provide a detailed review of the ecological modelling attempts of disturbed riparian vegetation.

Caskey et al. (2014) concentrated on the impacts of stream flow diversion on channel features and riparian vegetation in the Colorado Rocky Mountains' downstream areas. Observations of Borisade et al. (2021) in the African gallery forests revealed that riparian forests are disappearing more quickly, and the primary causes of this loss are notably deforestation, agriculture, and urbanisation. Similarly, Koskey et al. (2021) identified that the riparian vegetation of the Njoro and Kamweti Rivers, Kenya, had been impacted by human-centred disturbances. Also, the study by Cao (2021) found similar results from central Japan. Nsor et al. (2021) recognised that if there are major disturbances, delicate native species can become extinct, and only stress-tolerant alien invasion species will remain in the riparian zones. Sanou et al. (2021) studied a disturbed woody riparian vegetation corridor in the Boucle du Mouhoun, Western Burkina Faso, and suggested that rare species need enrichment planting in order to maintain their population. The abundance and diversity of species were low along streams adjacent to agricultural land, where riparian buffers were too narrow and highest along streams within forests, where riparian buffers were wider. Thus, a positive correlation between species richness and buffer width was identified by Alemu et al. (2023). The findings of Ruto et al. (2023) highlight the threats to the riparian plant community due to human-led activities and the need for environmental managers to intensify education on riparian conservation and management.

Chapter - 3

Chapter - 3

ELUCIDATING THE HETEROGENEITY IN THE BIOCLIMATIC REGIMES WITHIN THE ANAMALAI LANDSCAPE OF THE WESTERN GHATS

3.1. Introduction

Bioclimatology is an ecological science which looks into how climate affects the distribution of species and communities. This began with research on the relationships between temperature, precipitation, and plant community distribution in vegetation studies. The climatic parameters that are physiologically significant to plant growth and dispersal are known as bioclimatic variables (Bazan et al., 2015). Bioclimatic classification approaches link meteorological data to the geographic distribution regions of living organisms, primarily individual plant species or plant communities (Peinado et al., 2012). It is also called Phyto climatology and investigates the reciprocity between climate and the distribution of living things and their communities on Earth. It began to take shape due to connecting numerical climate values with species, formations, and plant community distribution areas, which later incorporated knowledge of landscape phytosociology and biogeocenosis (Molero & Marfil, 2015). The availability of more detailed data on vegetation distribution, as well as changes in the structure and composition of natural potential vegetation and its sub-stages as a result of climatic, edaphic, geographic, and anthropogenic influences, are facilitating the identification of bioclimates and natural potential vegetation boundaries with more accuracy and objectivity (Marfil et al., 2017).

An early definition of bioclimatics states that it is a field of science that looks into the relationship between life, climate, the seasons, and geographic distribution. It focuses on fundamental laws, principles, systems, and methods of application in general research and economic practice, with particular reference to the major and minor effects of the principal terrestrial and astronomical laws of causation as represented by the variable phenomena of life, climate, and seasons, relative to the geographic coordinates as expressed, measured and interpreted in units of time, temperature, and distance (Hopkins, 1938). Francis and Yukon Ecological Land

Classification Working Group (2008) defines Bioclimatic zones as locations with similar regional climates. Each zone has a "reference" vegetation community known as the reference site. According to Meher-Homji (1962), the term "Bioclimate" refers to the climate about life and is characterised by an aridity-humidity index, which is formed based on integrating three crucial ecological factors: temperature, precipitation, and dry months. The main focus of a climatic classification is to distinguish the climatic regions according to the meteorological parameters, such as temperature and precipitation, which significantly influence the Earth's landscapes (Meher-Homji, 1980).

3.1.a. Bioclimate, terrain features and vegetation interrelationship

The Western Ghats' hilly topography and complex physiography support various bioclimates and corresponding vegetation types (Pascal, 1982). The various types of vegetation are caused by changing climatic factors such as temperature and rainfall. The temperature varies according to altitude and topography. The combined interaction of climatic, edaphic, and biotic factors in space and time determines an area's vegetation. On the other hand, the local climate is influenced by rainfall, temperature, and the length of the dry season. As a result, bioclimate is a critical component in determining the types of vegetation and its dynamics in each region (Meher-Homji, 2001). Bachan (2010) asserts that rainfall, altitude, or topography cannot determine a landscape's possible microclimatic variations. The existence of diverse community composition inside a rainfall-altitude regime provides evidence for the cumulative effects of rainfall, temperature (a measure of altitude), and the number of wet months in a year to define a (pioneer, seral, and climax) community. The climax types were classified as primary vegetation types of the respective bioclimate, while the rest were classified as secondary or successional vegetation types. Thus, rainfall (precipitation), temperature, and the length of the dry months determined a region's bioclimate to understand different riparian forest communities (Meher-Homji, 2001; Bachan, 2010).

3.1. b. Bioclimatic classification

As the climate is a complicated phenomenon, two or three factors cannot adequately define the climate of an area. Hence, climate classification must consider multiple factors (Fang et al., 2002). The pioneering efforts in comprehensive bioclimatic studies include the Worldwide bioclimatic classification system by Rivas-Martinez (1981, 1987, 1993, 2002); the Classification of bioclimates of the Greek area (Tselepidakis & Theoharatos, 1989); the Classification of bioclimates of Chile by Amigo and Ramirez (1998), in this he identified five bioclimatic zones in Chile. Following these critical works, Barber and Crespo (2001) studied bioclimatology and potential vegetation of Mexico's Yucatan Peninsula. Hossell et al. (2003) provided bioclimatic classification for Britain and Ireland. Agro-bioclimatic classification for arid and semiarid lands in the isoclimatic Mediterranean zones given by Le Houerou (2004). Pineda-Martínez et al. (2007) classified bioclimatic zones of the central-north-eastern region of México. Bioclimatic classification of Isfahan province was given by Yaghmaei et al. (2009), who utilised a multivariate statistical method for the classification of bioclimate. Soltani et al. (2011) has given bioclimatic classification for Chahar-Mahal and Bakhtiari province. Pesaresi et al. (2014) studied bioclimate of Italy. Bazan et al. (2015) provided a bioclimatology and vegetation series in Sicily. Khatibi et al. (2016) published a bioclimatic classification for central Iran. Choi et al. (2017) gave a bioclimatic classification of Northeast Asia. Peinado et al. (2018) studied and classified vegetation in the US based on bioclimate. Mobolade and Pourvahidi (2020) provided a climatic classification for Nigeria, and Alba et al. (2021) classified the bioclimate of the Apulian region for table grape production and to assess climate change. These are the significant approaches for bioclimatic classification across the globe.

Pioneering and comprehensive works on bioclimatology and bioclimatic vegetation classification from the Indian region came during the same periods. Major climatic classification of the phytogeographic zones of India by Meher-Homji (1982) was the first comprehensive work from India. This was followed by bioclimatic forest classification by Gadgil and Meher-Homji (1982), bioclimate of the Western Ghats (Pascal, 1982), wet evergreen forest of the Western Ghats of India (Pascal, 1988), bioclimatology and plant geography of Peninsular India (Meher-Homji, 2001). The pioneering work on the bioclimatic study of riparian zones and vegetation from the Indian region was given by Bachan (2003, 2005, 2010). Bachan et al. (2014) identified four bioclimatic regions, i.e., Dry, Moist Deciduous, Evergreen, and Wet evergreen, within the Chalakudy River basin of the

Western Ghats. Bachan (2010) classified the riparian forests of the Chalakudy River basin based on the identified four bioclimatic regions, and this can be considered a pioneering work on the bioclimatic classification of riparian forests from the Indian region. No further attempts emerged from the Western Ghats or Indian region towards a bioclimate based approach to studying the riparian zones.

3.1.c. Mapping of bioclimatic areas

A bioclimatic map displays a compilation of the climatic factors of unique biological significance for a particular region (Tselepidakis & Theoharatos, 1989). Previous climate categorisation concepts are insufficient for providing accurate cartographic expression, and climate mapping, on the other hand, becomes scientifically difficult in places with differing ecological configurations. Bioclimatic maps are used as baseline data for predicting distribution patterns of possible historic forest types, a benchmark to demonstrate and analyse land use cover change, a data source for investigating potential links between isobioclimates and certain land uses, and it is expressed as a baseline to forecast the consequences of climate change (Gopar-Merino et al., 2015). This is also used to map ecological conditions, provide natural resource managers with analytical tools to assess conservation policies, map ecological niches, or model species distribution ranges (Perrin et al., 2020). Rivas-Martinez (1996) provided a bioclimatic map of Europe. Following this, Mesquita and Sousa (2009) mapped the bioclimate of mainland Portugal using geostatistical approaches. Gopar-Merino et al. (2015) applied bioclimatic mapping in the province of Michoacan. UNESCO-FAO (1963) prepared a bioclimatic map of the Mediterranean zone. Xuan et al. (2021) prepared a bioclimatic vegetation map of Vietnam's Ba and Kone River Basin, a pioneering study on bioclimatic mapping from a river basin. Pascal (1982) mapped bioclimates of the Western Ghats, the only significant attempt at bioclimatic mapping in the Indian region.

Thus, there are significant gaps in bioclimatic delineation and classification, particularly in the Indian subcontinent, home to several ecoregions, biodiversity hotspots, and unique riparian zones of many rivers that originate and flow through variable landscapes. Studies connecting bioclimate and riparian zones have not emerged yet from the Western Ghats, except Bachan (2010). Hence, the primary emphasis of the present chapter is to identify heterogenic bioclimatic regimes across the Anamalai landscape by evaluating meteorological and topographical information about the landscape and, revealing bioclimatic zones of the Anamalai landscape and connecting the dots. Study of riparian zones of each river basin of this complex landscape, the Anamalai, one of the critical landscapes of Southern Western Ghats, needs an in-depth understanding and delineation of the heterogenic bioclimatic zones within.

3.2. Methodology

The bioclimate is defined primarily by the Number of dry months, Temperature and Rainfall (Meher-Homji, 2001). For the identification of heterogenic bioclimatic regimes, meteorological data were gathered from 37 stations (Indian Meteorological Department (IMD) Pune -26 stations; Kerala State Electricity Board - 2 stations; Private rain gauge stations -3 stations; Forest Department -1 station) and rainfall data collected for the Chalakudy Basin by Bachan (2010) (5 stations). Among these, 15 stations were eliminated due to missing data and lack of data on rainy days. Therefore, a total of 22 meteorological station data over a period of 10 to 25 years are utilised for the final analysis. The locations of meteorological stations in the study area are provided in Appendix I.

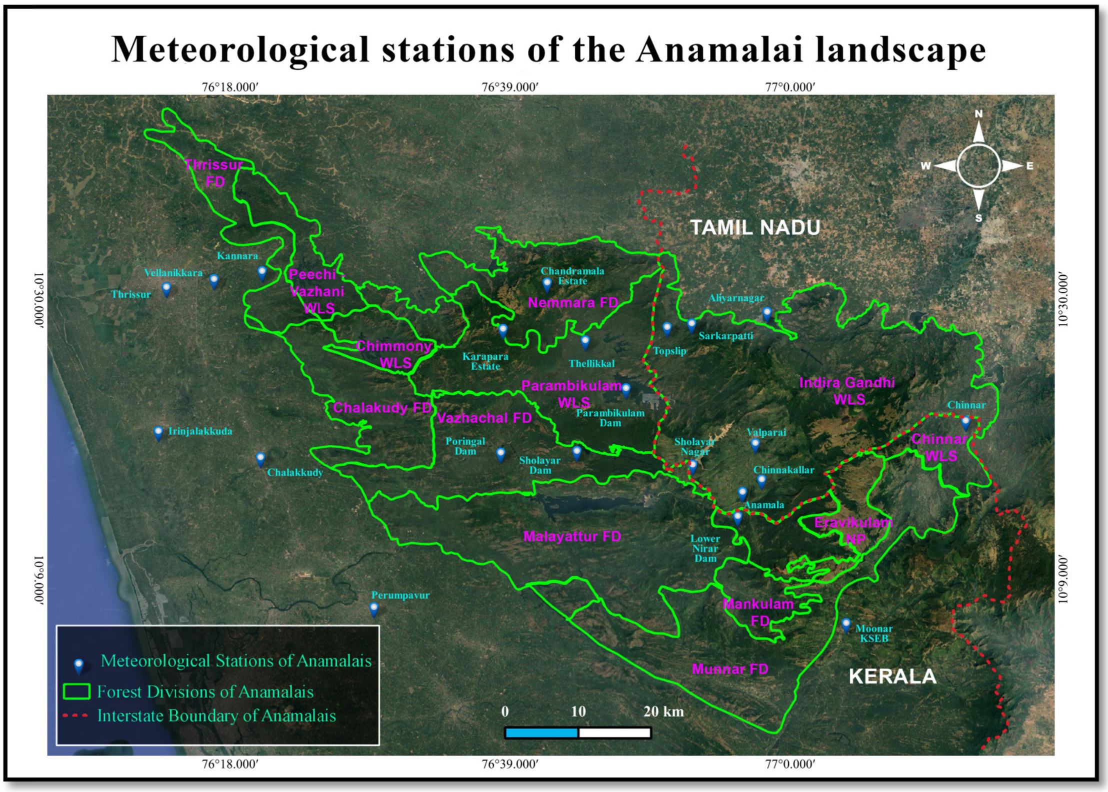


Fig. 3.1. Meteorological stations of the study area

The temperature data gaps were filled by using data from the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project (https://power.larc.nasa.gov/data-access-viewer/) based on its higher reliability (Quansah et al., 2022; Pandey et al., 2022; Ahmed et al., 2022). The data was entered to analyse and delineate the bioclimatic zones within the Anamalai landscape. The exceptional years with higher variations from the mean values that emerge due to climatic oscillations coupled with El Nino and recent global warming are challenging when compiling climatic data for analysing bioclimatic values (Bachan, 2010). Such exceptional years were identified and removed from the data of each station based on standard deviation to obtain cleansed data and a diverse bioclimate as suggested by Meher-Homji (2001) and improvised by Bachan (2010) and Bachan et al. (2014).

According to Meher-Homji (2001) and Bachan (2010), an area's bioclimate can be determined by examining three essential parameters: i. Annual average precipitation (R) (in mm), ii. The mean temperature of the coldest months (t) of the year (in°C), and the iii. Number of dry months to represent the length of the dry season. Annual average precipitation (R) was calculated from the mean values of monthly precipitation data, and the monthly average temperature of the coldest month was considered for calculating the mean temperature of the coldest months in a given area. Bagnouls and Gaussen (1953) define dry months as those months in which the average monthly precipitation (P) in mm is less than or equal to twice the average monthly temperature (2T) in ^{0}C.

$$\mathbf{P \leq 2T = Dry\ month}$$

Meher-Homji (2001) for Peninsular India and Bachan (2010), in the Chalakudy River basin, successfully used this methodology. This method is adopted here for mapping and analysis of the bioclimatic heterogeneity of the Anamalai landscape. The location of meteorological stations was plotted in the physical maps, including elevation and contour maps derived from SRTM satellite imagery, using the open-source GIS platform QGIS software (Ver. 3.22). According to Meher-Homji (2001) and Bachan (2010), these data were classified into various bioclimates based on their differences in the three important factors.

3.3. Results

3.3.a. Cross-sectional/topographic profile of the Anamalai landscape

A topographic profile of the Anamalai landscape was created in three regions for a better understanding of the landscape and its topographical features along three lines covering different zones such as the lower elevation, high elevation and very high elevation (Fig. 3.2.). Line A represents the northern portion of the Anamalai landscape covering the Nelliyampathy hills, line B through the centre portion covering the Eravikulam plateau and line C at the southern portion of the Munnar landscape.

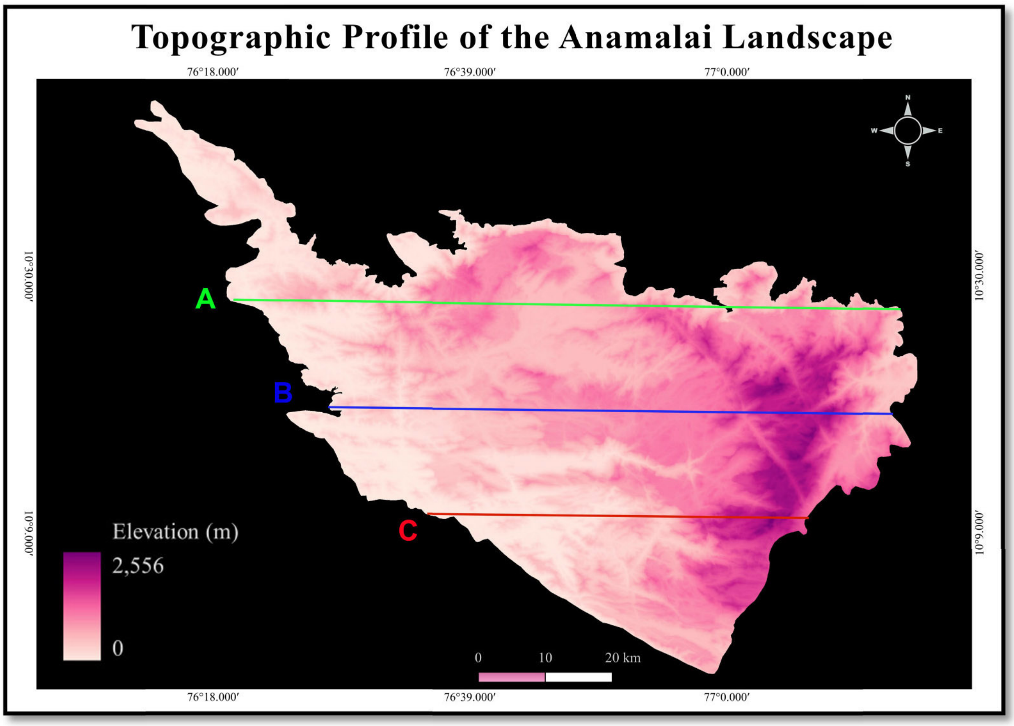


Fig. 3.2. Cross-sectional/topographic profile of the Anamalai landscape

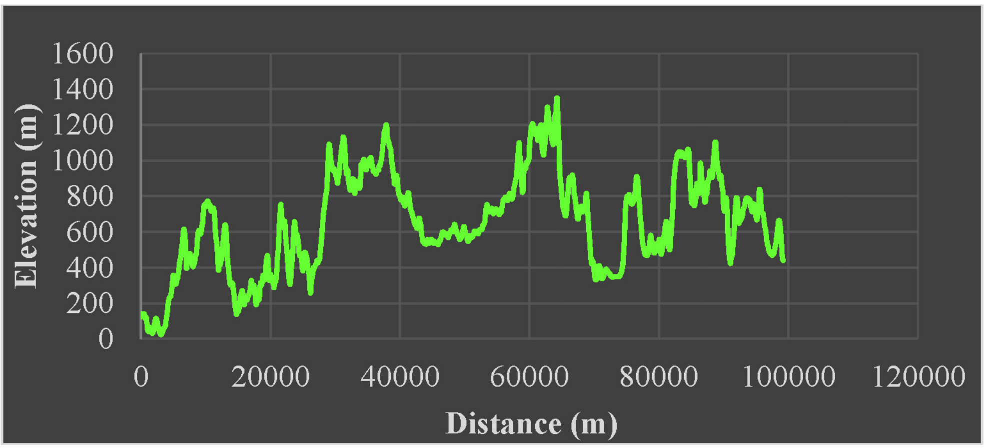


Fig. 3.3. Cross-sectional/topographic profile of the Anamalai landscape - Northern portion (Line A)

Line A represents the North-Eastern portions of the landscape (Palakkad-Peechi and Coimbatore), which cover the forest areas of the Thrissur Forest division, Peechi-Vazhani Wild Life Sanctuary, Chimmony Wild Life Sanctuary, Nemmara forest division, and portions of Parambikulam Wild Life Sanctuary and Anamalai Tiger Reserve. The line passing through the Nelliyampathy hills (1200 m) represents the higher elevation peaks (Fig. 3.3.).

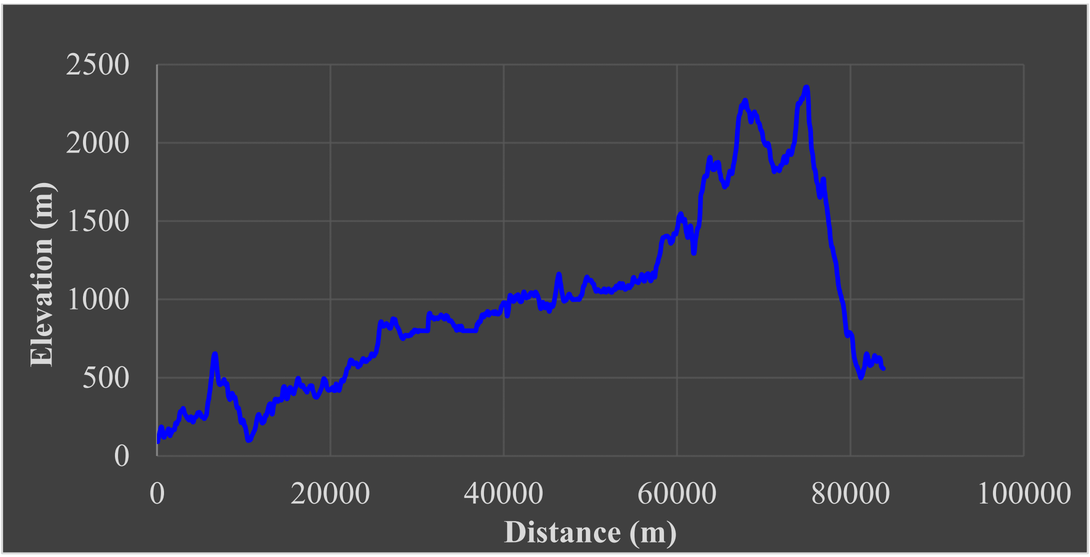


Fig. 3.4. Cross-sectional/topographic profile of the Anamalai landscape - Middle portion (Line B)

Line B, in the middle (Fig. 3.4.), represents the Tumburmuzhy, Athirappilly and Vazhachal regions of the lower western slopes (<1000m) and also the relatively high elevations (1500-2300m) towards the east (Sholayar and Valparai areas), and after a certain point, the elevation falls significantly (1000-500m) at the eastern slopes of the Anamalai landscape. This region is covered by the Chinnar Wildlife Sanctuary of Kerala and the adjoining part of the Anamalai Tiger Reserve of Tamil Nadu, representing the rain shadow regions of the landscape.

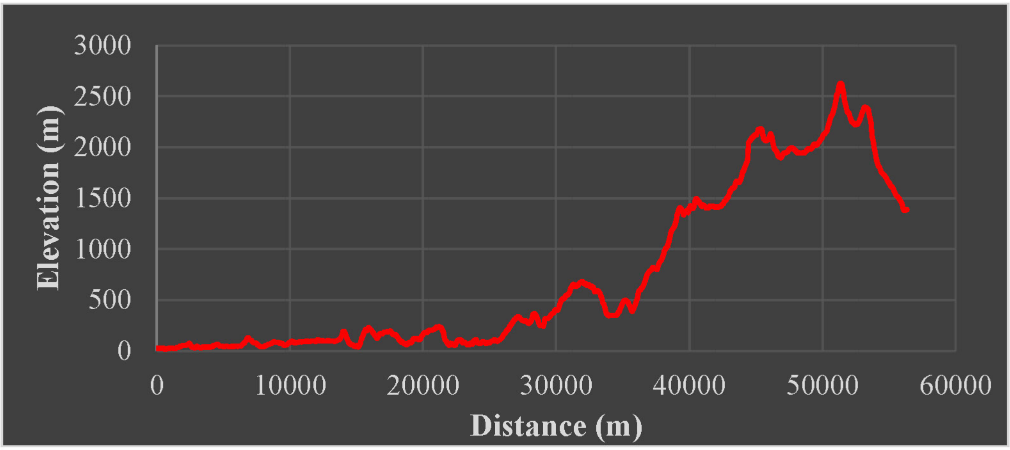


Fig. 3.5. Cross-sectional/topographic profile of the Anamalai landscape - Southern portion (Line C)

In the southern portions of the Anamalai landscape (Fig.3.5.), the lower peaks in the graph (100-800m) on the northern side of the landscape cover the portions of the Malayattur forest division, representing the Idamalayar and Pooyamkutty valleys. Towards the southeast, it represents the higher elevation regimes (>1500m) of the Munnar forest division and the Eravikulam National Park areas, especially the Anamudi peak (2695 m). Then, the elevation gradually reduces in the eastern slopes of the landscape (2400 to 1400m).

3.3. b. River basins within the Anamalai landscape

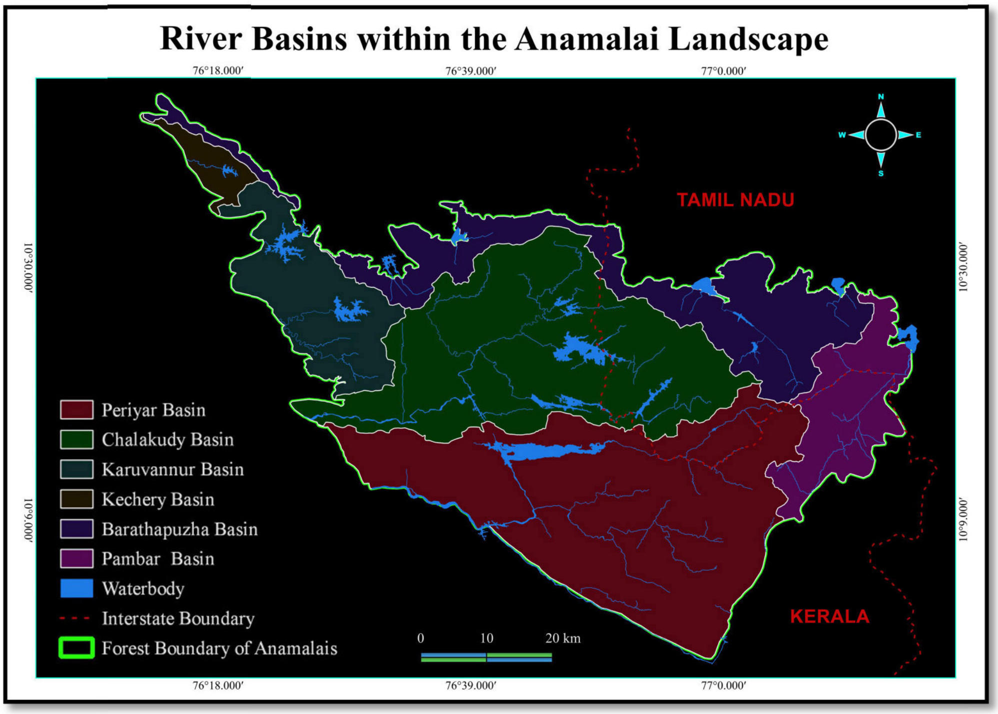


Fig. 3.6. River basins within the Anamalai landscape

Table 3.1. River basin area within the Anamalai landscape

Sl. No.	Basin Name	Basin area within the Anamalai landscape (km^2)
1	Periyar	1465
2	Chalakudy	1228
3	Bharathapuzha	679.25
4	Karuvannur	411.28
5	Pambar	338.3
6	Kechery	78.17
Total		4200

The Periyar Basin (34.88 % or 1465 km^2) covers the largest area within the Anamalai landscape (4200 km^2). This is followed by the Chalakudy basin, the second largest basin, whose significant portion is inside the Anamalai landscape and has an area of 1228 km^2 (29.23 %). The remaining river basins, like Bharathapuzha, cover an area of 16.17% (679.25 km^2), including portions of the tributary Aliyar, which flows through the Anamalai Tiger Reserve (423.4 km^2) of Tamil Nadu. Then comes the Karuvannur River basin, which covers 9.79 % (411.28 km^2) of the western portion of the landscape. Pambar basin, with an area of 8.05 % (338.3 km^2), which includes portions of Anamalai Tiger Reserve and Chinnar Wild Life Sanctuary. Finally, the Kechery basin covers the least basin area compared to the other five river basins of the Anamalai landscape (78.17 km^2 or 1.86 %).

3.3.c. Bioclimatic zones of the Anamalai landscape

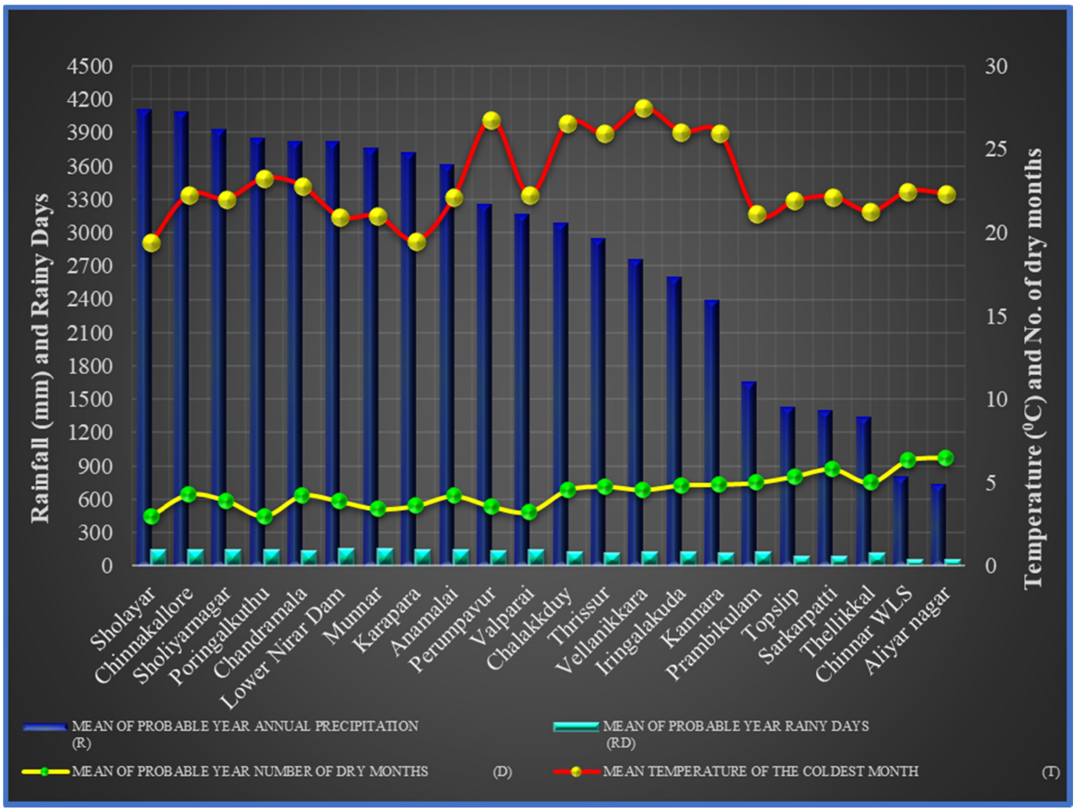


Fig. 3.7. Rainfall, Rainy days, Number of dry months (Mean probable year), and Mean temperature of the coldest month for the meteorological stations of the Anamalai landscape

Fig. 3.8. to 3.13. depicts the rainfall and temperature data gathered from the meteorological stations. Appendix II and Appendix III give detailed data on Mean monthly rainfall, Temperature, and Number of dry Months, Average and mean Probable year Rainfall, Number of rainy days, and Number of dry Months for all meteorological stations of the Anamalai landscape, respectively.

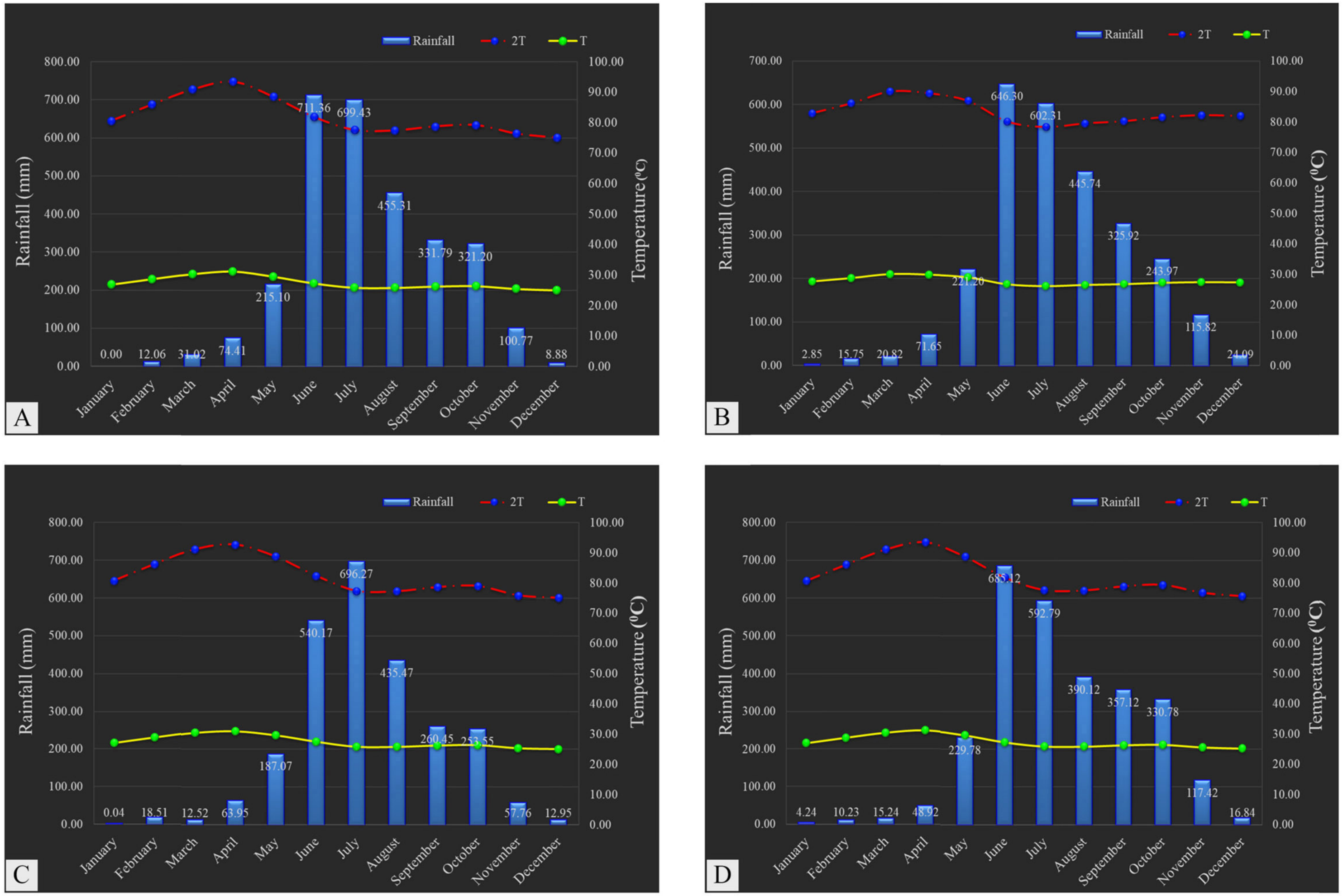


Fig. 3.8. Meteorological data derived from the meteorological stations across the Anamalai Landscape: A. Thrissur; B. Vellanikkara; C. Kannara; D. Irinjalakuda.

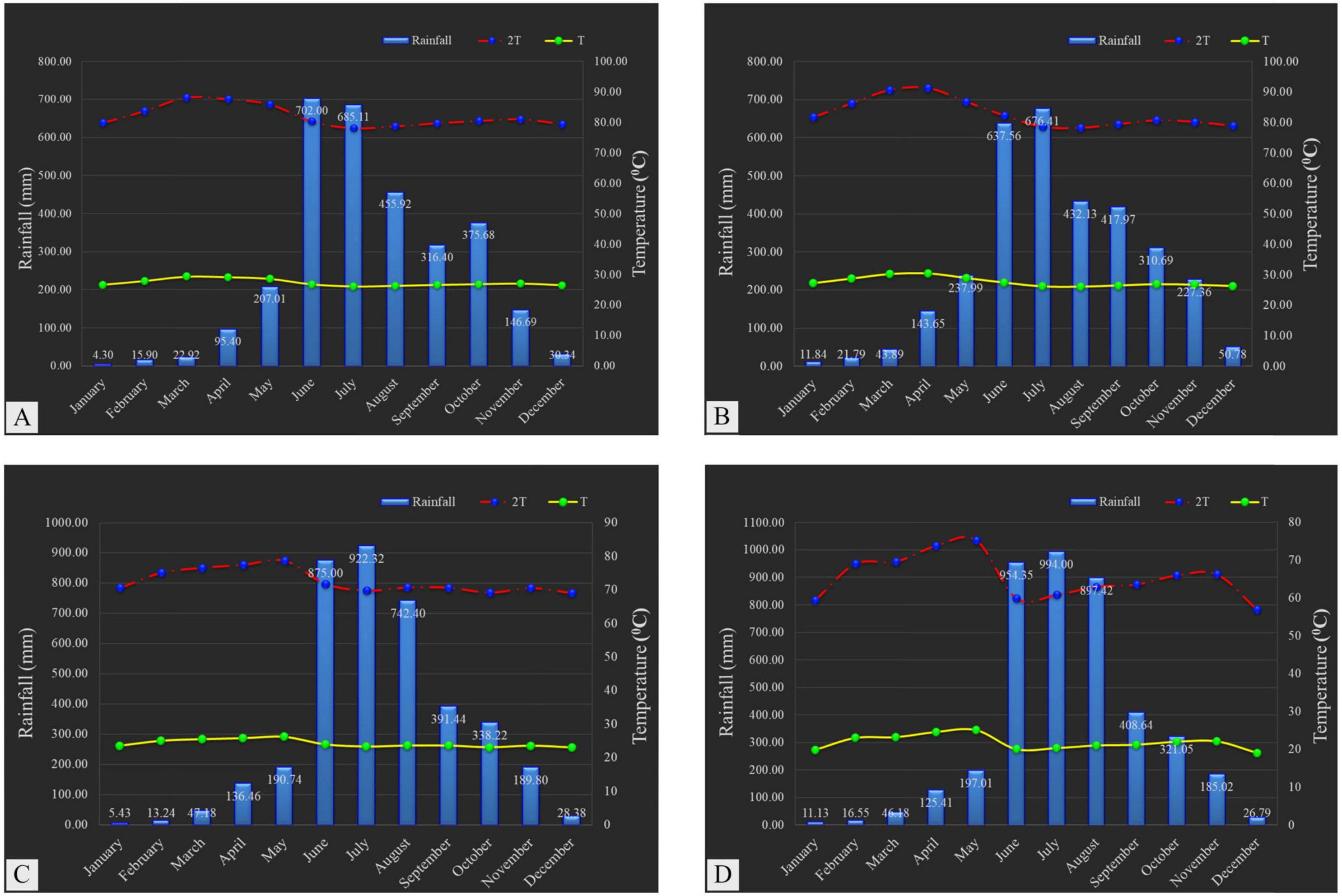


Fig. 3.9. Meteorological data derived from the meteorological stations across the Anamalai Landscape: A. Chalakudy; B. Perumpavur; C. Poringalkuth; D. Sholayar.

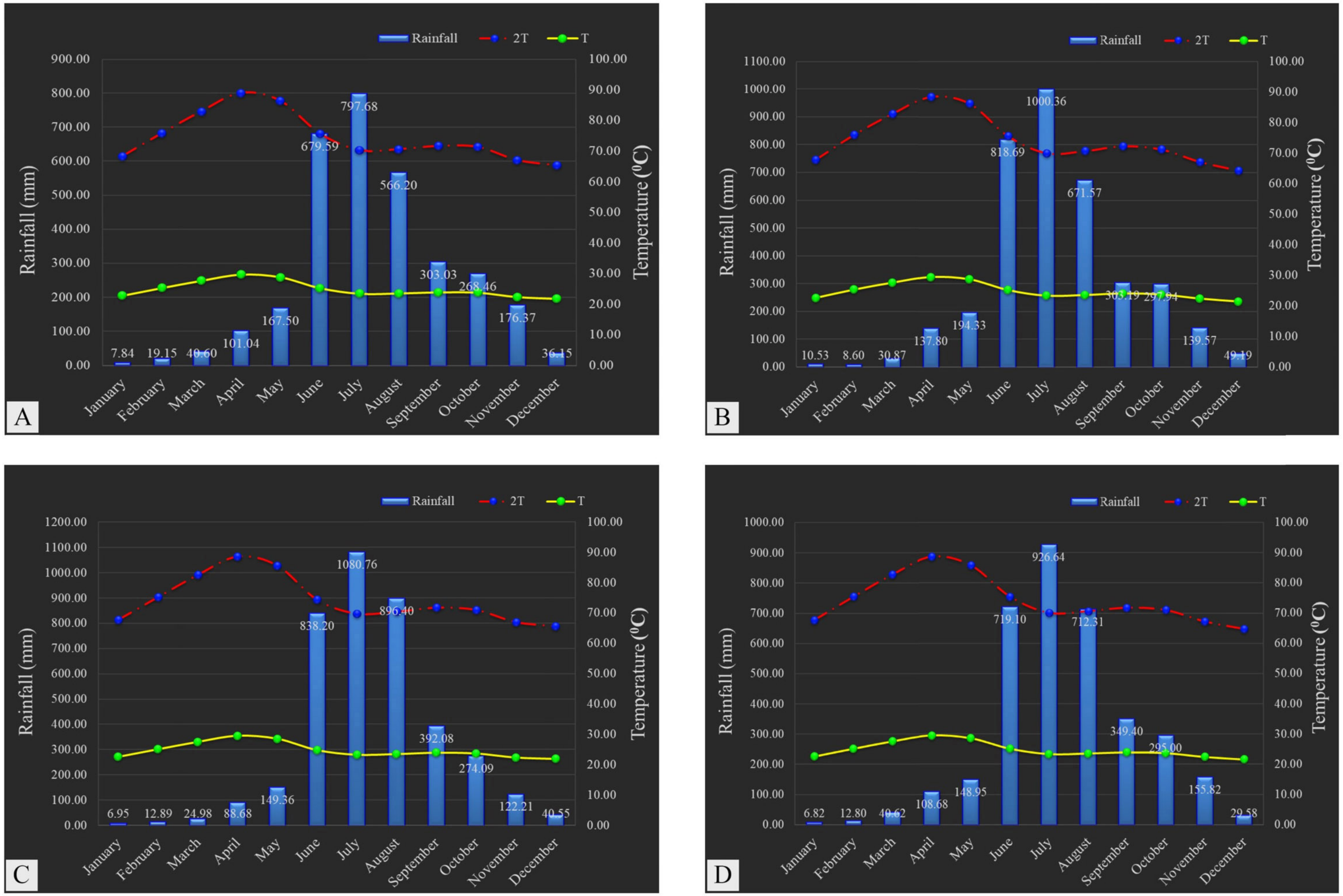


Fig. 3.10. Meteorological data derived from the meteorological stations across the Anamalai Landscape: A. Valparai; B. Sholayarnagar; C. Chinnakallore; D. Anamalai.

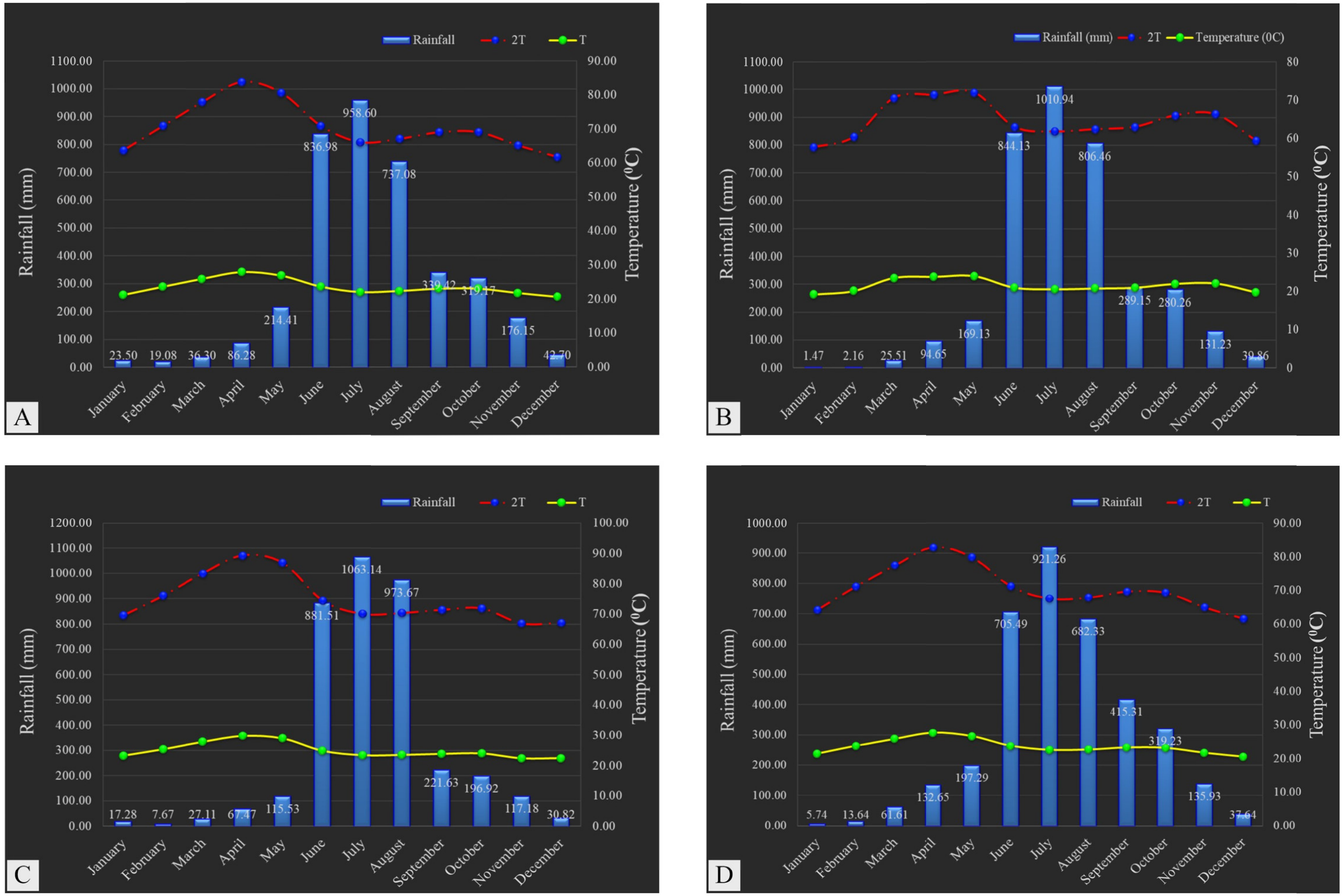


Fig. 3.11. Meteorological data derived from the meteorological stations across the Anamalai Landscape: A. Lower Nirar; B. Karapara; C. Chandramala; D. Munnar.

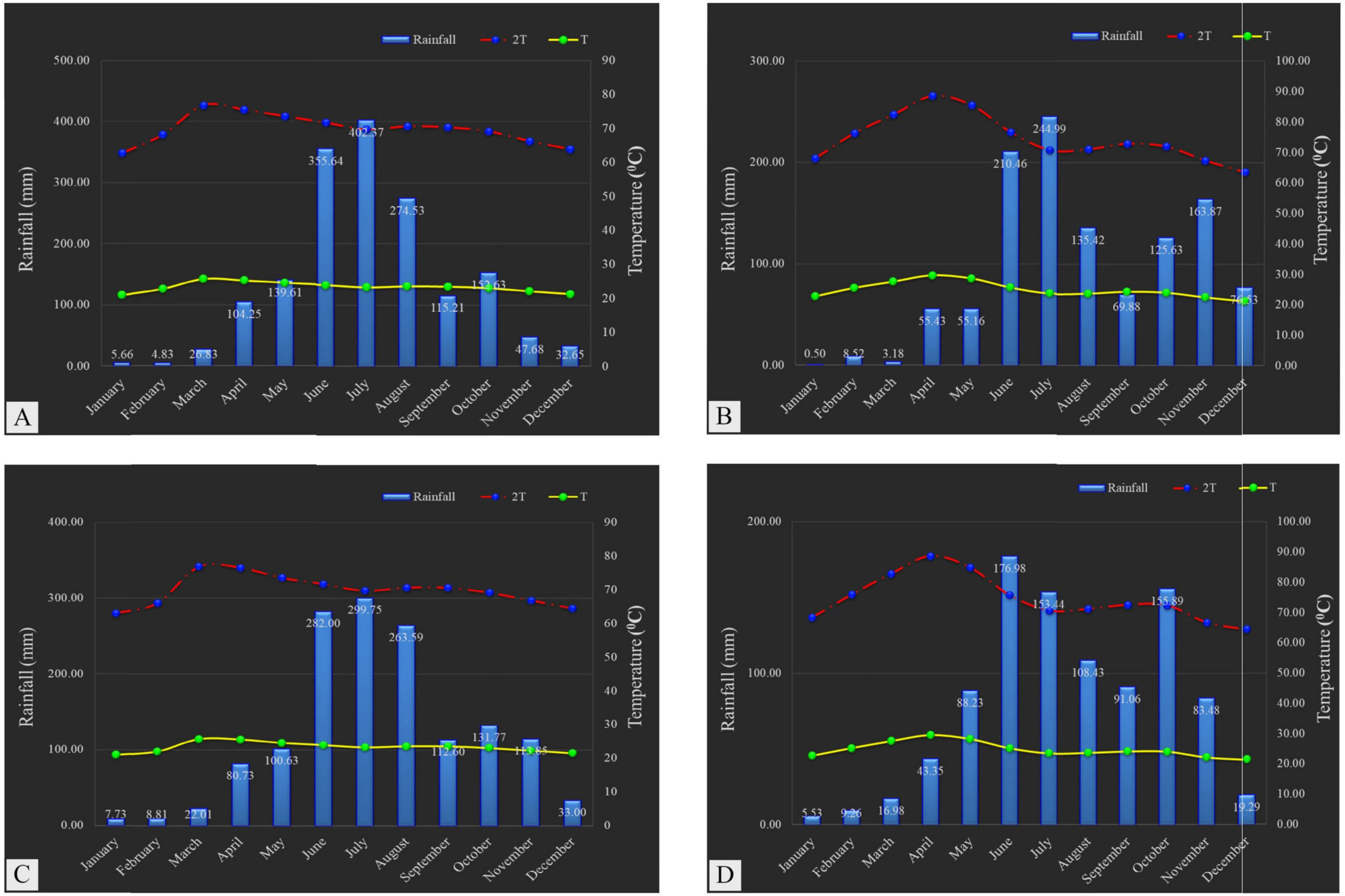


Fig. 3.12. Meteorological data derived from the meteorological stations across the Anamalai Landscape: A. Parambikulam; B. Topslip; C. Thellikkal; D. Sarkarpatti.

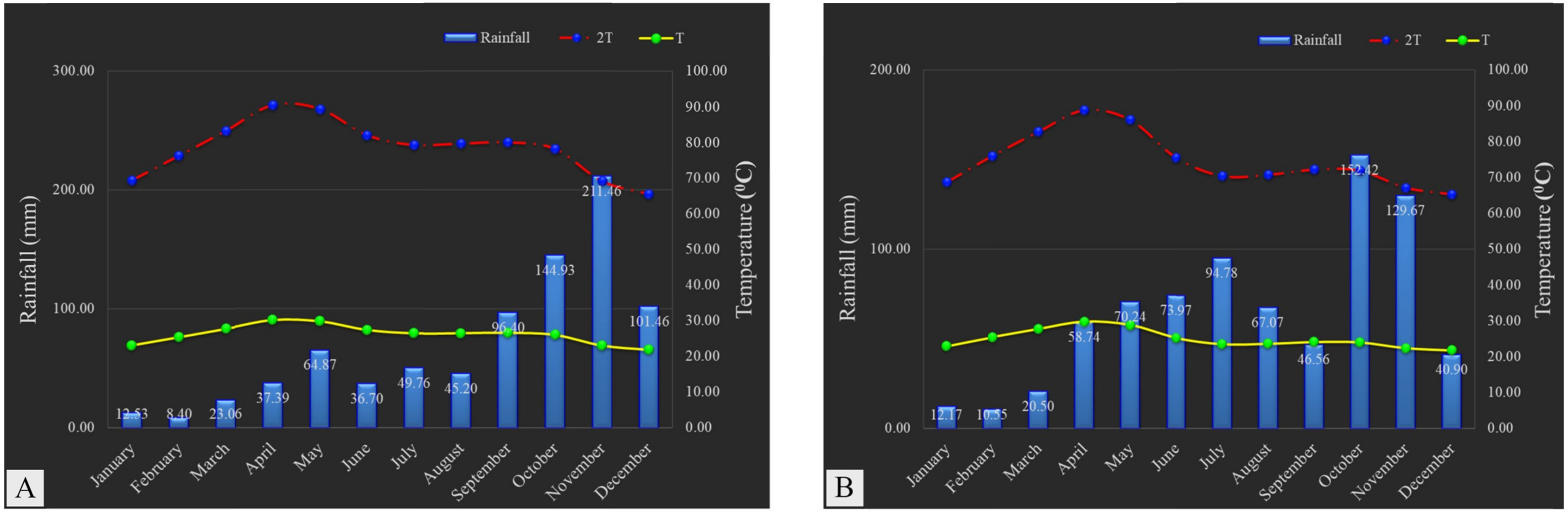


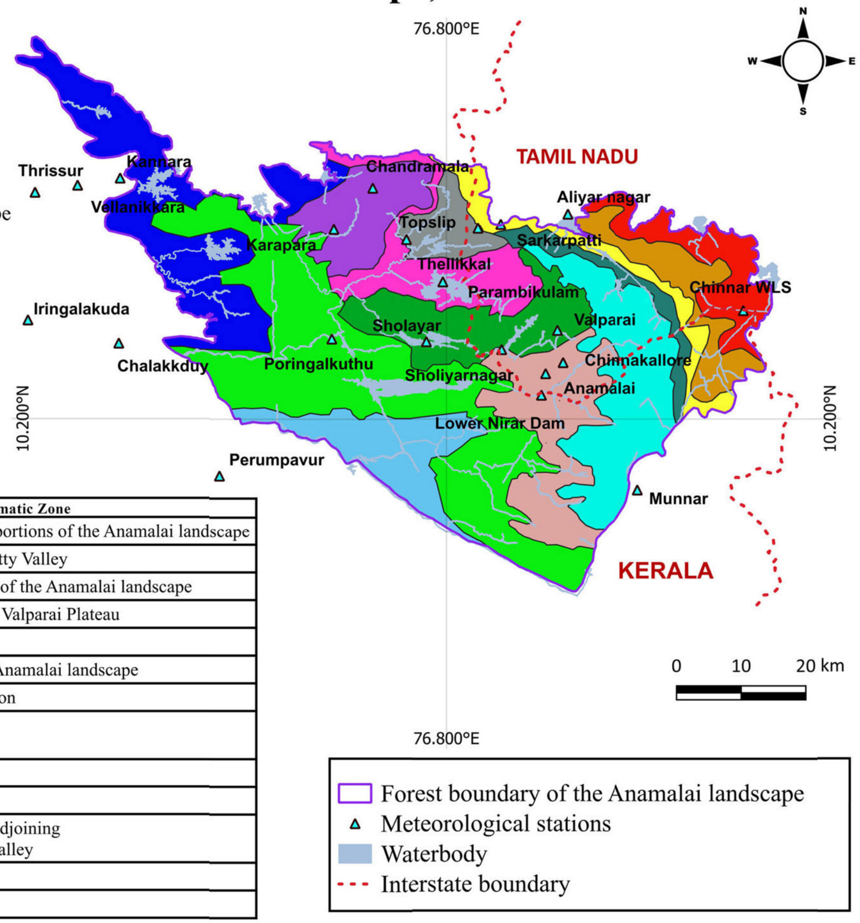
Fig. 3.13. Meteorological data derived from the meteorological stations across the Anamalai Landscape: A. Chinnar; B. Aliyarnagar.

Table 3.2. Identified bioclimatic zones within the Anamalai landscape

Sl. No.	Bioclimatic Zones		Area (km2)
1	Zone 1	Thrissur Peechi North-West portions of the Anamalai landscape	539.31
2	Zone 2	Kuttampuzha and Pooyamkutty Valley	263.6
3	Zone 3	Low elevation western slope of the Anamalai landscape	1029
4	Zone 4	Sholayar Valley and Northern Valparai Plateau	320.7
5	Zone 5	Southern Valparai Areas	376.8
6	Zone 6	Nelliyampathy areas of the Anamalai landscape	225.8
7	Zone 7	Munnar and Eravikulam region	440.1
8	Zone 8	Eastern edges of Munnar, Valparai plateau adjoining Munnar	92.39
9	Zone 9	Parambikulam valley	269.5
10	Zone 10	Top slip region	115.4
11	Zone 11	Eastern slope of Anamalai adjoining Sarkarpatti, Aliyar, Chinnar, Maraur valley	144.6
12	Zone 12	Maraur and Aliyar Valleys	183.6
13	Zone 13	Chinnar valley	199.2
Total			4200

Bioclimatic Zones of the Anamalai Landscape, Western Ghats

- Zone1 - Thrissur Peechi North -West portions of the Anamalai landscape
- Zone 2 - Kuttampuzha and Pooyamkutty Valley
- Zone 3 - Low elevation western slope of the Anamalai landscape
- Zone 4 -Sholayar valley and Northern Valparai Plateau
- Zone 5 - Southern Valparai areas
- Zone 6 - Nelliyampathy areas of the Anamalai landscape
- Zone 7 - Munnar and Eravikulam region
- Zone 8 - Eastern edges of Munnar,Valparai plateau adjoining Munnar
- Zone 9 - Parambikulam valley
- Zone 10 - Top slip region
- Zone 11 - Eastern slope of Anamalai adjoining Sarkarpatti, Aliyar, Chinnar, Maraur valley
- Zone 12 - Maraur and Aliyar valleys
- Zone 13 - Chinnar valley



No.	T	R	Dry months	Bioclimatic Zone
1	>23	2000-3500	4.5 - 5	Zone1 - Thrissur Peechi North -West portions of the Anamalai landscape
2	>23	2000-3500	3.5	Zone 2 - Kuttampuzha and Pooyamkutty Valley
3	>23	3500-5000	3	Zone 3 - Low elevation western slope of the Anamalai landscape
4	>23	3500-5000	3 - 3.5	Zone 4 -Sholayar valley and Northern Valparai Plateau
5	<23	3500-5000	3.8 - 4.2	Zone 5 - Southern Valparai areas
6	<23	3500-5000	3.5 - 4	Zone 6 - Nelliyampathy areas of the Anamalai landscape
7	<23	3500-5000	3 - 3.4	Zone 7 - Munnar and Eravikulam region
8	<23	1500-2000	4 - 4.5	Zone 8 - Eastern edges of Munnar, Valparai plateau adjoining Munnar
9	>23	1500-2000	5 - 5.5	Zone 9 - Parambikulam valley
10	>23	1200-1500	5 - 5.5	Zone 10 - Top slip region
11	>23	1200-1500	5.5 - 6	Zone 11 - Eastern slope of Anamalai adjoining Sarkarpatti, Aliyar, Chinnar, Maraur valley
12	>23	900-1200	5.5 - 6	Zone 12 - Maraur and Aliyar valleys
13	>23	600-900	6 - 7	Zone 13 - Chinnar valley

Fig. 3.14. Bioclimatic zones of the Anamalai landscape.

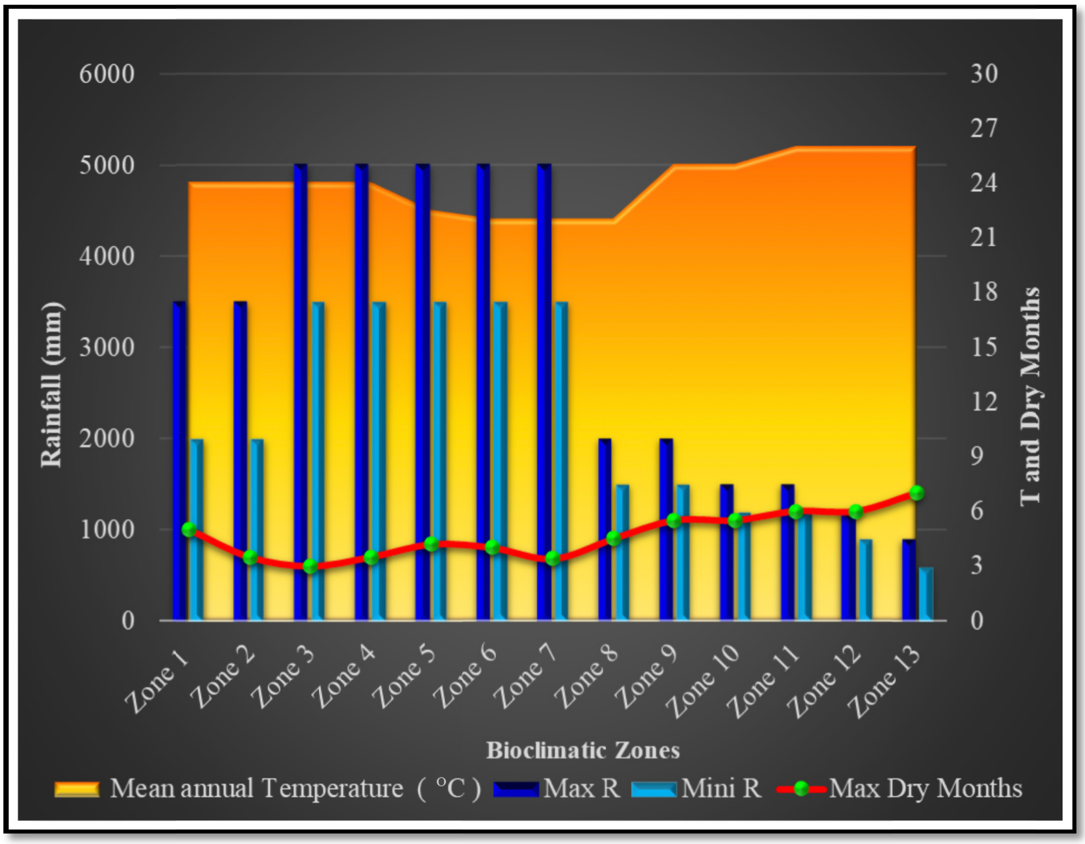


Fig. 3.15. Meteorological data for the identified bioclimatic zones of the Anamalai landscape

The bioclimatic analysis brought out 13 different bioclimatic zones across the Anamalai landscape (Fig. 3.14.) with characteristic variations in the Mean annual temperature (^{0}C), Average rainfall (mm), and Number of dry months based on the meteorological data collected from 22 meteorological stations of the Anamalai landscape. The zones are as follows:

- Zone 1 - Thrissur Peechi North-West portions of the Anamalai landscape
- Zone 2 -Kuttampuzha and Pooyamkutty Valley
- Zone 3 - Low elevation western slope of the Anamalai landscape
- Zone 4 - Sholayar Valley and Northern Valparai Plateau
- Zone 5 - Southern Valparai Areas
- Zone 6 - Nelliyampathy areas of the Anamalai landscape
- Zone 7 - Munnar and Eravikulam region
- Zone 8 - Eastern edges of Munnar, Valparai plateau adjoining Munnar
- Zone 9 - Parambikulam valley
- Zone 10 - Top slip region

- Zone 11 - Eastern slope of Anamalai landscape adjoining Sarkarpatti, Aliyar, Chinnar and Maraur Valley,
- Zone 12 - Maraur and Aliyar valleys
- Zone 13 - Chinnar valley.

Among these, nine zones belong to the Mean annual temperature (^{0}C) >23^{0}C, with variations in Average rainfall (mm) and Number of dry months in between them and they are positioned on opposite slopes of the Anamalai landscape. The remaining four zones belong to mean annual temperature (^{0}C) < 23 ^{0}C covering the higher elevation areas of the landscape such as Zone 5 -Southern Valparai Areas, Zone 6 -Nelliyampathy areas of Anamalai landscape, Zone 7 -Munnar and Eravikulam region and Zone 8 -Eastern edges of Munnar, Valparai plateau adjoining Munnar. The bioclimatic zones of each river basin are detailed in Chapter 4 of the study, along with the results of riparian vegetation mapping.

3.4. Discussion

The Anamalai landscape experiences various climatic conditions, with mean annual temperatures and average rainfall varying from lower to higher elevation ranges (100 m – 2695 m). Orographic effects lead to spatial variation in precipitation on the eastern and western slopes of the landscape. Topography, elevation, and the windward side slope of a barrier all work together to produce orographic effects on rainfall. Compared to a mountain with a lower height and a gradually shifting slope, a mountain with a higher elevation and a sudden change in slope tends to restrict precipitation at its foot (Nair, 1991; Tawde & Singh, 2014; Halder et al., 2022). The Anamalai landscape's western slopes with average rainfall range from 5000 to 1500 mm (Zone 1 -10), and the Eastern slope with 1500 to 600 mm (Zone 11- 13). Maximum precipitation occurs during the Southwest monsoon season (June – September) except for Chinnar and Aliyar Nagar rain shadow areas, with the highest precipitation in the northwest monsoon (October – December). The study identified 13 bioclimatic zones within the Anamalai landscape based on the variation in temperature, rainfall, and number of dry months due to the landscape's physiography and geographic position.

Table 3.3. Comparison of bioclimatic features of bioclimatic zones of the Anamalai landscape

<table>
<tr><th>Mean Annual T (^{0}C)</th><th>Average Rainfall (mm)</th><th>No. of Dry Months</th><th>Bioclimatic Zones</th><th>Area (km^2)</th></tr>
<tr><td rowspan="4">T> 23 ^{0}C</td><td rowspan="2">2000-3500</td><td>4.5 -5</td><td>Zone 1- Thrissur Peechi North-West portions of the Anamalai landscape</td><td>539.31</td></tr>
<tr><td>3.5</td><td>Zone 2 - Kuttampuzha and Pooyamkutty Valley</td><td>263.6</td></tr>
<tr><td rowspan="5">3500-5000</td><td>3</td><td>Zone 3 - Low elevation western slope of the Anamalai landscape</td><td>1029</td></tr>
<tr><td>3 -3.5</td><td>Zone 4 - Sholayar Valley and Northern Valparai Plateau</td><td>320.7</td></tr>
<tr><td rowspan="4">T < 23 ^{0}C</td><td>3.8 -4.2</td><td>Zone 5 - Southern Valparai Areas</td><td>376.8</td></tr>
<tr><td>3.5 -4</td><td>Zone 6 - Nelliyampathy areas of the Anamalai landscape</td><td>225.8</td></tr>
<tr><td>3 -3.4</td><td>Zone 7 - Munnar and Eravikulam region</td><td>440.1</td></tr>
<tr><td rowspan="2">1500-2000</td><td>4 -4.5</td><td>Zone 8 - Eastern edges of Munnar, Valparai plateau adjoining Munnar</td><td>92.39</td></tr>
<tr><td rowspan="5">T > 23 ^{0}C</td><td rowspan="2">5 -5.5</td><td>Zone 9 - Parambikulam valley</td><td>269.5</td></tr>
<tr><td rowspan="2">1200-1500</td><td>Zone 10 - Top slip region</td><td>115.4</td></tr>
<tr><td rowspan="2">5.5-6</td><td>Zone 11- Eastern slope of Anamalai adjoining Sarkarpatti, Aliyar, Chinnar, Maraur valley</td><td>144.6</td></tr>
<tr><td>900-1200</td><td>Zone 12 - Maraur and Aliyar Valleys</td><td>183.6</td></tr>
<tr><td>600-900</td><td>6-7</td><td>Zone 13 - Chinnar valley</td><td>199.2</td></tr>
<tr><td colspan="4">Total</td><td>4200</td></tr>
</table>

Within the Anamalai landscape, bioclimatic Zone 3 - The low-elevation western slope of the Anamalai landscape covers the highest area (1029 km^2), followed by Zone 1 - Thrissur Peechi North-West portions of the Anamalai landscape (539.31 km^2) and the least area covered by Zone 8 - Eastern edges of

Munnar, Valparai plateau adjoining Munnar (92.39 km^2). The highest rainfall is found in the western slope with elevations above 600 m, 3500-5000 mm, especially in the Sholayar, Valparai and Munnar areas and least in the eastern rain shadow regions (600-900 mm) like Chinnar and Attakatti areas. As a result of being bordered by the steep Sholayar and Nelliyampathy ridges and exposed to the arid Coimbatore plains via the Top Slip area despite its location on the western slope of the Western Ghats, the Parambikulam basin receives less rainfall (1500-2000 mm). These bioclimatic observations from the Anamalai landscape are consistent with findings by Bachan (2010) and Bachan et al. (2014), who discuss the bioclimate and riparian flora of the Chalakudy basin. The study extends these bioclimatic interpretations into the other five basins of the Anamalai landscape: Karuvannur, Kechery, Bharathapuzha, Pambar and Periyar.

A previous study by Ramesh et al. (2007) describes the rainfall fluctuations in the western Anamalai landscape unit (LU 16) and its coastal surroundings (LU13). The findings are congruent with the pioneering work by Pascal (1982), who explained the bioclimates of the Western Ghats with seven classes of rainfall in mm and nine classes of mean length of the dry season (1 to 2 up to 9 to 10 months) along the Western Ghats. The Western Ghats bioclimatic maps by Pascal (1982) have been digitised by Renard et al. (2009). Similarly, Legris and Viart (1961) studied Bioclimates of South India and Ceylon. Meher-Homji (2001) provided a classification of India's climate. In this study, he describes nine major climatic regimes for the Indian region; in his classification, the Anamalai landscape falls under the Tropical climatic type, which is the most prevalent climatic type in the Indian subcontinent, also separated into different subtypes based on temperature and dry months. It served as the basis for the present study and identified 13 bioclimatic zones under tropical climate type from the Anamalai landscape. Xuan et al. (2021) categorised and mapped the vegetation of Vietnam's Ba and Kone River Basin using three bioclimatic variables, including annual temperature, annual rainfall, and length of the dry season, and the resulting map showed the distribution of vegetation corresponding to 12 bioclimatic units, from low to high altitudes which is comparable to the current study. Hence, the study contributed to a detailed understanding of all the available bioclimatic zones within the Anamalai landscape of the Western Ghats and its river basins for the first time.

3.5. Summary

The Anamalai landscape is an important region in the Southern Western Ghats, with six major river basins within the landscape: the Chalakudy, Periyar, Pambar, Bharathapuzha, Karuvannur, and Kechery Basins. The study gives special emphasis to bioclimate zonation and mapping of the riparian vegetation of the Anamalai landscape. The present chapter deals with the bioclimatic zonation of the landscape. It acts as a base for the detailed study of the riparian forests of the landscape and supports the mapping and classification of riparian forest types. The bioclimatic analysis brings out thirteen different bioclimatic zones across the Anamalai landscape with characteristic variations in Mean annual temperature (^{0}C), Average rainfall (mm) and Number of dry months. Bioclimatic zones with comparatively higher rainfall are found on the west slopes of the landscape, with fewer dry periods covering the Thrissur, Nelliyampathy, Nemmara, Chalakudy, Vazhachal, Sholayar, Valparai, Malayattur, Mankulam, Munnar, Eravikulam regions (Zone 1to 7) except for Parambikulam areas (Zone 9 and 10). Less rainfall zones were found across the eastern slopes, with the highest number of dry months covering the basin areas of Pambar and Aliyar (Zone 8 and Zone 11 to 13). This understanding of bioclimatic heterogeneity and its zonation can help in elucidating the riparian vegetation types.

Chapter - 4

Chapter - 4

RIPARIAN VEGETATION MAPPING OF THE ANAMALAI LANDSCAPE

4.1. Introduction

Vegetation mapping is an essential technique for the classification, monitoring, and execution of natural area management strategies (Dias et al., 2004). A topographic base map that depicts vegetation units using the proper colours and symbols makes up a vegetation map, and the last step in a cognitive process is creating a vegetation map. This begins with field sampling of vegetation and progresses to characterising vegetation types through identifying and classifying plant groups or other units based on the various geobotanical disciplines (Pedrotti, 2013). Vegetation mapping is a crucial tool for managing natural resources and planning land use (Kuchler, 1988). Moreover, for studying succession, it is vital to analyse how plants respond to disturbances and the correlation between vegetation and other environmental influences. Mapping plant communities provides spatial information about the entire ecosystem and is part and parcel with understanding the environmental factors that control their distributions (Franklin, 2013).

4.1. a. Riparian vegetation mapping

The small, narrow width of riparian habitats presents various challenges for vegetation modelling. Consequently, in the past, field-based surveys have been used extensively for vegetation mapping and monitoring the riparian zones, but these techniques are quite time-consuming (Dilts et al., 2010). Vegetation mapping using GIS is a widely accepted approach with deep links to remote sensing, digital surveying mapping, and more conventional mapping and cartography methods (Bareth & Waldhoff, 2018) employed in this study to map riparian vegetation. To comprehend how vegetation changes through time and space, riparian vegetation needs to be mapped and monitored (Mathooko & Kariuki, 2000). To better understand the extent and decline of these ecosystems, high-quality maps are required, along with a careful assessment of uncertainty (National Research Council, 2002; Ward et al., 2002). Administrators and researchers can utilise this information to enhance decision-making by estimating the percentage of riparian zones affected by anthropogenic activities with known estimates of uncertainty (Salo & Theobald, 2016). Vegetation maps are widely used to assist in the identification and prioritisation of conservation and restoration areas; forest type density stratification to get details on the dynamic link between the different levels of vegetation degradation; planning, management, and conservation for a sustainable future; can be used for comparing future vegetation changes and get assistance to planning management strategies for the present and future.

The German naturalist and explorer Von Humboldt's work at the start of the 18th century marked the beginning of vegetation mapping. However, it took more than a century for the practice to become a profession (Jelaska, 2009). Since the middle of the 20th century, efforts to map vegetation have increased for land use planning and cataloguing natural resources primarily as paper maps (Brzeziecki et al., 1993). Cartographic considerations, issues with using colour and symbols, and about the ineffective vegetation maps were discussed in methods in vegetation ecology (Mueller-Dombois & Ellenberg, 1974; Kuchler & Zonneveld, 1988). Champion (1936) created a map of Indian forest vegetation, updated by Champion and Seth (1968). A detailed history of mapping was provided by Gupta and Tyagi (1992). Using GIS, maps can be stored as digital data, making it easier to add attributes and segregate those attributes into different map layers (Franklin, 2013).

Studies of the riparian forests of low-elevation areas of Chalakudy River by Bachan (2003) was the first in the country to map the riparian vegetation of a river. The other significant studies include Song et al. (2018) riparian vegetation mapping of the Lake Tana basin and the mapping and characterisation of Southern Western Ghats tropical riparian evergreen forests by Bachan et al. (2022). Pooja and Bachan (2022), using QGIS software, mapped the riparian vegetation of the Chinnar River, one of the small tributaries of the Pambar River of Kerala. The vast majority of research on riparian mapping utilised remote sensing technology and Google Earth Engine (Goetz, 2006; Yang, 2007; Akasheh et al., 2008; Evangelista et al., 2018; Pu et al., 2021; Rommel et al., 2022). However, visual interpretation approaches are preferred in riparian vegetation mapping due to the small, narrow, linear and distinctive distribution patterns of the riparian vegetation (Song et al., 2018).

Regarding mapping and quantitative estimation of the distribution area of riparian forests, fewer attempts were reported from the Indian region (Bachan, 2003; Bachan et al., 2022; Pooja & Bachan, 2022). The Riparian vegetation map provides detailed data on the distribution of riparian vegetation in the Anamalai landscape. It can be used to prioritise riparian areas for conservation and restoration. Moreover, this vegetation map can be used as primary data for studying changes in land use, restoration ecology, landscape ecology, ecological modelling, and hydrological modelling. This will contribute to site-specific management and conservation of riparian forests of the Anamalai landscape, especially the degraded riparian zones, to enhance the regeneration of the riparian forests.

The mapping of riparian vegetation of the Anamalai landscape shall fill the gaps in our knowledge regarding different aspects of riparian vegetation, especially in the mapping and bioclimatic demarcation of riparian vegetation. This is the first attempt to prepare a riparian forest map using Google Earth Pro and QGIS 3.22 software from the region and a crucial step in the conservation of forests considering the river basin as a unit. Hence, this chapter explains the riparian vegetation map of the major rivers within the Anamalai landscape as dense, medium-dense and degraded types.

4.2. Methodology

4.2.a. Preparation of base map

Survey of India toposheets (SoI) covering the Anamalai landscape 58B/2, 58B/6, 58B/7, 58B/8, 58B/10, 58B/11, 58B/12, 58B/14, 58B/15, 58B/16, 58C/13, 58F/2, 58F/3, 58F/4, 58G/1 with a scale of 1:50000 georeferenced in the QGIS 3.22 software and used for the preparation of a base map of the study area.

4.2.b. Preparation of physical map

The Anamalai landscape boundary was demarcated using QGIS 3.22 software based on Singh (1971), contour map and previous works done in the study area (Nair, 1991; Ramesh & Gurukkal, 2007; Baskaran et al., 2013). The drainage network is accurately represented by digitising all the rivers, tributaries and streams within the Anamalai landscape using Survey of India Toposheets. Significant locations, roads, basin boundaries, administrative forest boundaries, and interstate boundaries were demarcated separately using recorded GPS readings, toposheets, and aerial images (Google). Physical characteristics like the extent of the administrative area and basin area were calculated from the prepared maps.

4.2.c. Preparation of thematic maps

The Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) data with 30 m spatial resolution for the Anamalai landscape from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/) was used for the preparation of the thematic maps of the Anamalai landscape. The DEM was then clipped using the Anamalai landscape boundary using the raster extraction tools of QGIS 3.22 to get the DEM of the study area. This clipped DEM was used to create slope and aspect maps using raster analysis tools, and the contour maps prepared from raster extraction tools and elevation profiles were derived using terrain profile tools of QGIS 3.22.

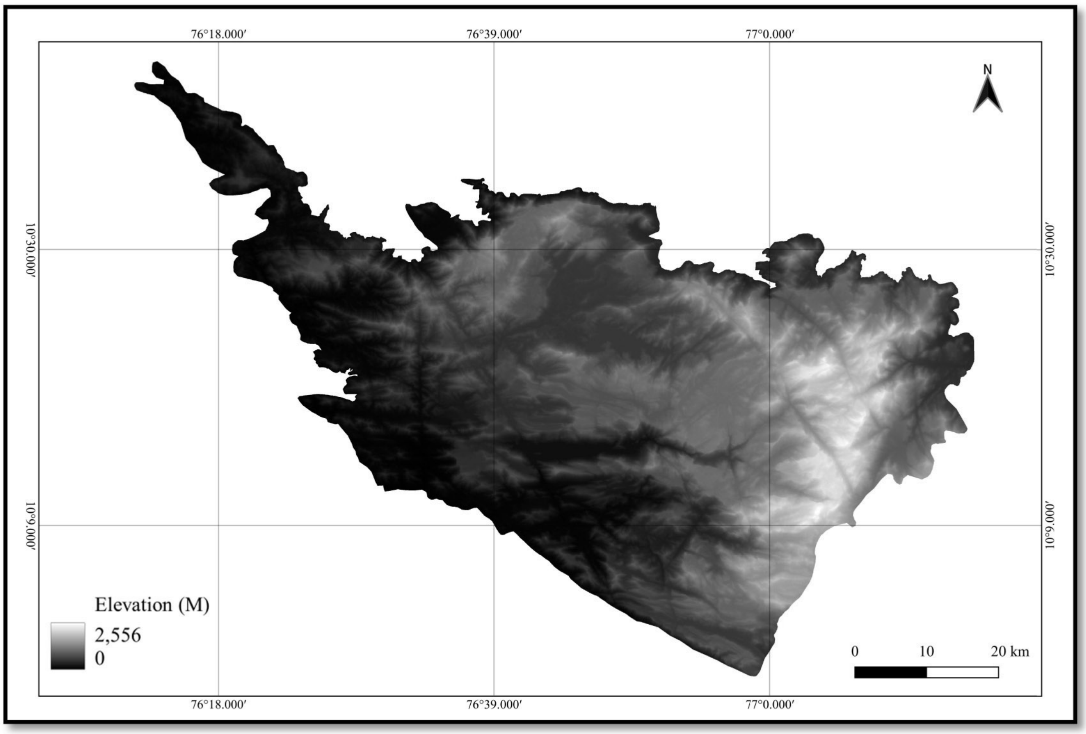


Fig. 4.1. SRTM 30 m spatial resolution DEM of the Anamalai landscape downloaded from USGS Earth Explorer

4.2.d. Preparation of riparian vegetation maps

The distribution of riparian forests within the Anamalai landscape was mapped using high-resolution satellite images from Google Earth Pro and QGIS 3.22 software (Bachan & Pooja, 2017; Song et al., 2018). Within the six river basins of the Anamalai landscape (i. Chalakudy, ii. Karuvannur, iii. Periyar, iv. Pambar, v. Bharathapuzha and vi. Kechery), the distribution of riparian forest was mapped in detail for major rivers and their important tributaries. Google Earth is a virtual map of the world that uses a combination of satellite images and aerial photographs and provides other information such as roads, places, and political boundaries (Duhl et al., 2011; Song et al., 2018).

The visual interpretation method was employed for riparian forest mapping due to the too-narrow distribution and failure or inaccurate riparian stretch detection and merging of surrounding vegetation types when using automatic classification methods. Visual interpretation of high-resolution imagery has been crucial in delineating and verifying land cover, particularly in complex ecosystems (Song et al., 2018; Kutz et al., 2022). The "Add polygon tool" of Google Earth Pro was used to vectorise (KML File). The KML files are then exported to QGIS 3.22 software and converted to shape files for further analysis of each vegetation type.

The historical imagery tool in Google Earth Pro facilitates confirming vegetation and land use by comparing satellite images from various periods in the same place. It also helps to identify riparian forests in cloudy and foggy photos. However, the present study used imagery from 2019 to 2022 to map riparian forests. The prepared thematic maps and physical map of the Anamalai landscape using the SRTM digital elevation model (DEM) depicting the contours, slopes, aspects, and elevation profile of the Anamalai landscape assist in identifying terrain features for better data interpretation and increase the accuracy of riparian vegetation mapping using Google Earth Pro which is detailed in Chapter 1 of the study. Mapping the riparian vegetation of the wet tropics is challenging compared to delineating riparian forests within a dry deciduous landscape where it is physiognomically visible. Even though canopy breaks and ground truthing are used here to delineate the riparian zone, the identified heterogenic bioclimatic riparian vegetation units are colour-coded on the map separately as dense, medium-dense, and degraded riparian forests.

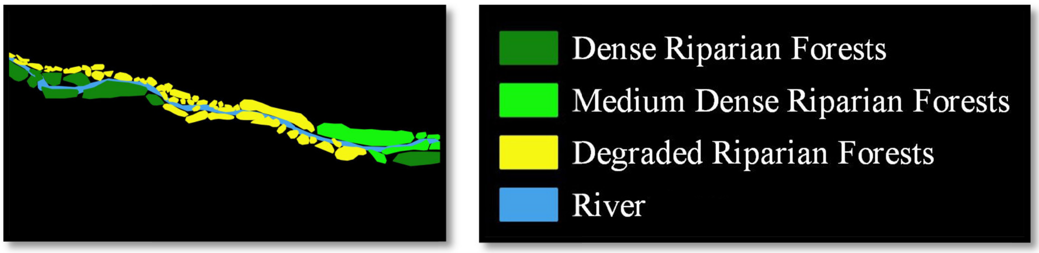


Fig. 4.2. Colour code used for riparian vegetation mapping

Field verification surveys improve the accuracy of vegetation mapping, and it is preferable to conduct visual interpretations by one person to avoid multiple interpretations on one single observation, which will increase the accuracy of riparian vegetation mapping (Song et al., 2018). Ground truthing and field verification of the identified vegetation units were done for representative samples, along with fieldwork in the phytosociological sampling and transect data collection phase of the research.

4.3. Results

4.3.a. Mapping of riparian vegetation of the Anamalai landscape

The Anamalai landscape's riparian vegetation mapping was not attempted by any research work except for the Chalakudy River basin (Bachan, 2003). Being a narrow linear vegetation with unique characteristics, the riparian vegetation could be mapped only with visual observation and ground truthing for better precision. Previous trials and studies indicate the automatic derivation of riparian vegetation from the satellite imageries resulting in problems with wrong interpretation since the narrow vegetation is difficult to differentiate from other neighbouring vegetation types, especially in the rainfed or evergreen regions (Bachan et al., 2022). As a result, visual interpretation techniques, along with field verification are always recommended when studying riparian vegetation, which is applied here. The identification or interpretation keys for Google Earth images based on ground truthing are shown in Fig. 4.3. and 4.4.

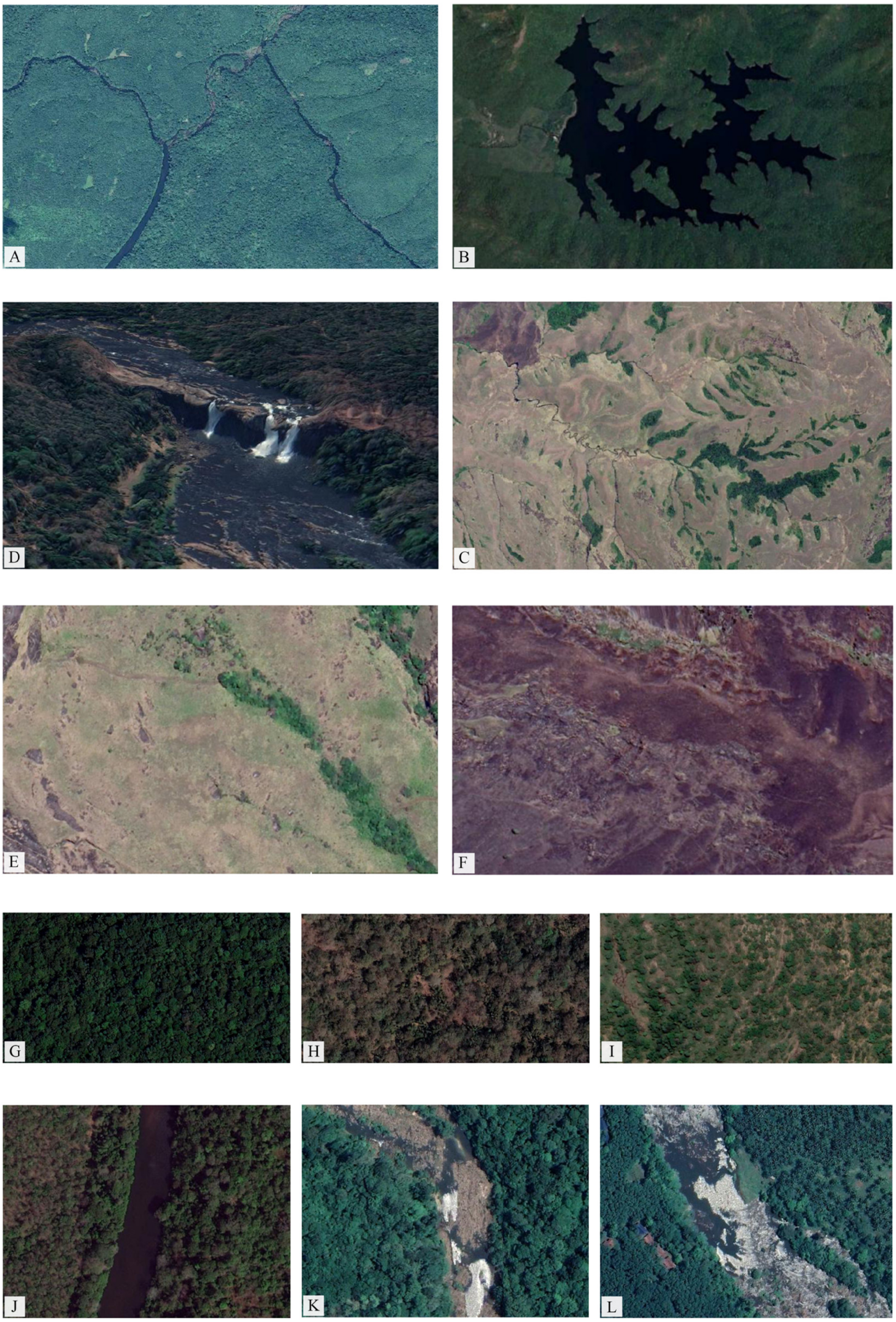


Fig. 4.3 Identification Key for Visual Interpretation of the Google Earth Images: A. Rivers; B. Reservoir; C. Streams; D. Waterfalls; E. Grassland; F. Open Rocky areas; G. Evergreen forests; H. Moist deciduous forest; I. Dry deciduous forest; J. Dense Riparian Forest; K. Medium Dense Riparian Forest; L. Degraded Riparian Forest.

Fig. 4.4 Identification Key for Visual Interpretation of the Google Earth Images: A. Island; B. Agriculture Land; C. Human Settlements; D. Roads; E. Gravel Roads; F. Bridge; G. Timber Plantations (Wet season); H. Timber Plantations (Dry season); I. Tea Plantations; J. Oil palm Plantations; K. Bamboo /Reeds (Wet season); L. Bamboo /Reeds (Dry season).

4.3. b. Bioclimate and riparian vegetation of the Anamalai landscape

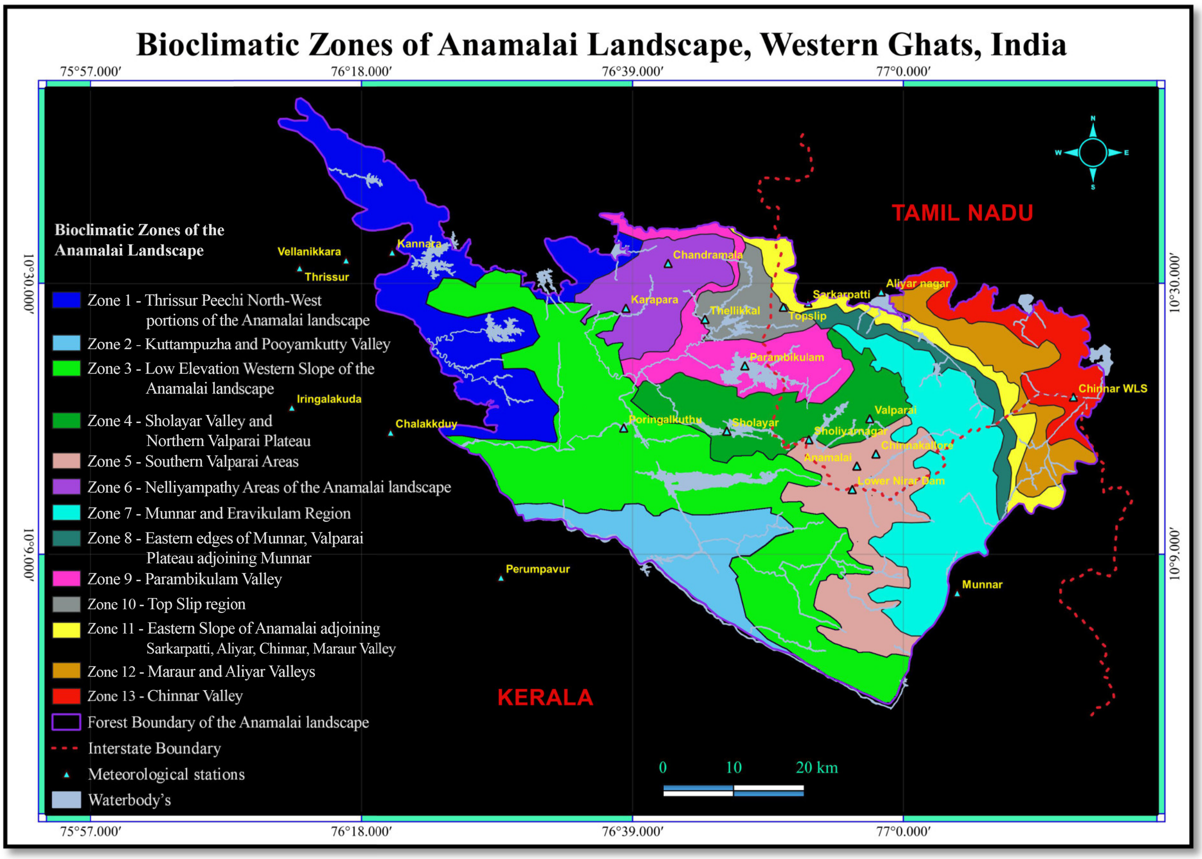


Fig. 4.5. Bioclimatic zones of the Anamalai landscape

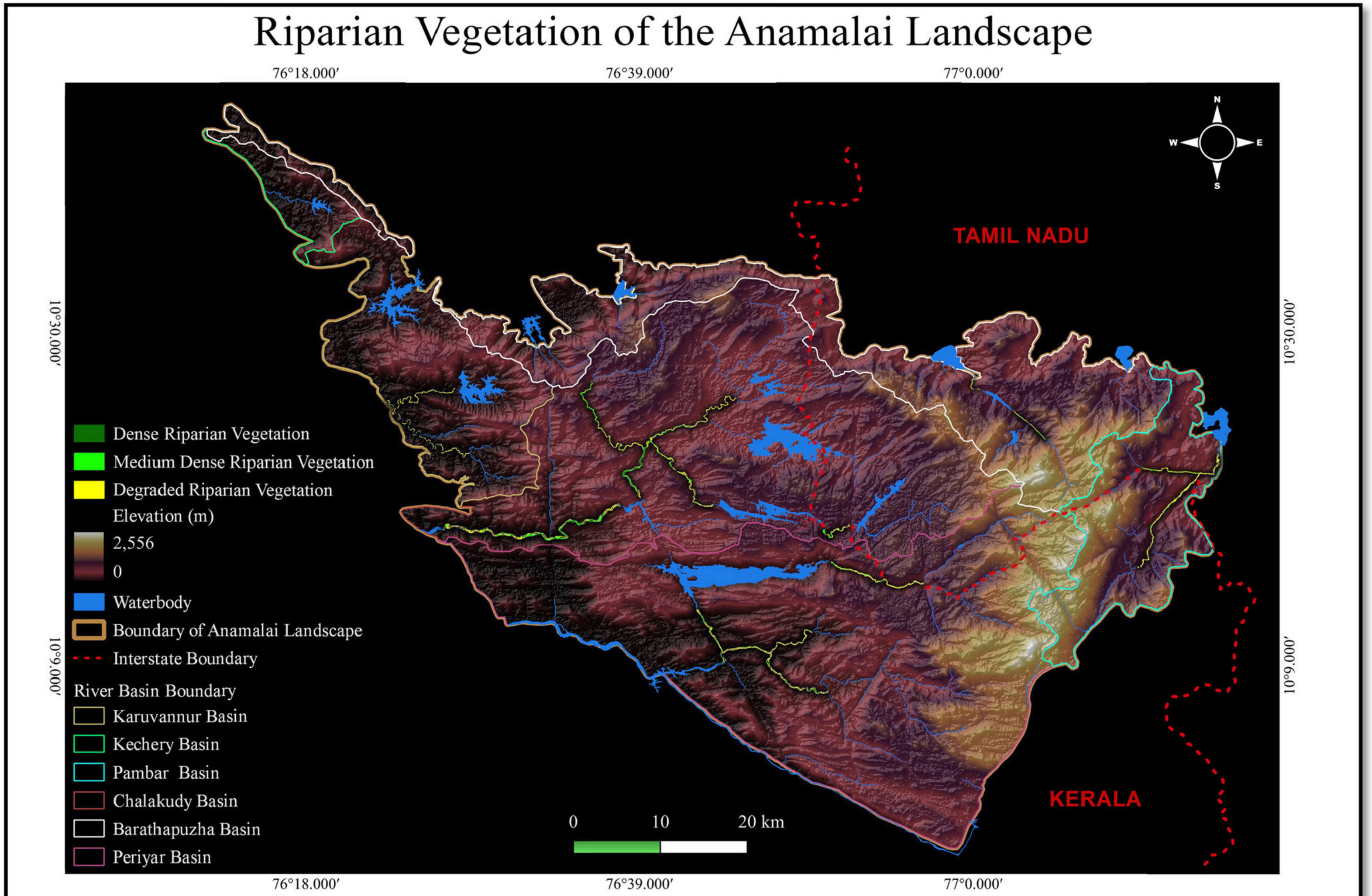


Fig. 4.6. Riparian vegetation map of the Anamalai landscape.

Table 4.1. Riparian vegetation of the Anamalai landscape unit

Sl. No.	Vegetation Type	Chalakudy Basin (ha)	Karuvannur Basin (ha)	Periyar Basin (ha)	Bharathapuzha Basin (ha)	Pambar Basin (ha)	Total (ha)
1	Dense Riparian Forests	85.10	0.00	3.39	0.00	3.30	91.79
2	Medium dense Riparian Forests	171.97	0.00	27.10	5.47	18.51	223.05
3	Degraded Riparian Forests	187.52	23.41	92.90	7.84	70.56	382.23
Total		444.59	23.41	123.39	13.31	92.37	697.06

According to the study, the Anamalai landscape comprises 697.06 ha of riparian forest along the five major river basins of the Anamalai landscape. Of which the dense riparian forest accounts for 13.17 % (91.79 ha), the medium dense riparian vegetation accounts for 32 % (223.05 ha), and the degraded riparian forest accounts for 54.83 % (382.23 ha). The Chalakudy River covers the most significant extent of riparian forest (444.59 ha). Followed by the Periyar River (123.39 ha), Pambar River (92.37 ha), and Karuvannur River (23.41 ha), the least riparian forest area is covered by the Bharathapuzha basin (Aliyar River- 13.31 ha). In the present study using Google Earth Pro software, dense and medium-dense riparian vegetation units were identified with an accuracy of 85% and the degraded riparian vegetation types and plantations with maximum accuracy (100 %).

Table 4.2. Accuracy of riparian vegetation identification

Sl. No.	Vegetation Type	Dense Riparian Forests (%)	Medium Dense Riparian Forests (%)	Degraded Riparian Forests (%)	Plantations (%)
1	Dense Riparian Forests	85	15	0	0
2	Medium Dense Riparian Forests	15	85	0	0
3	Degraded Riparian Forests	0	0	100	0
4	Plantations	0	0	0	100

4.3.c. River basin vice riparian vegetation distribution of the Anamalai landscape

4.3.c.i. Chalakudy basin within the Anamalai landscape

- **Longitudinal elevation profiles and bioclimate of the Chalakudy River basin**

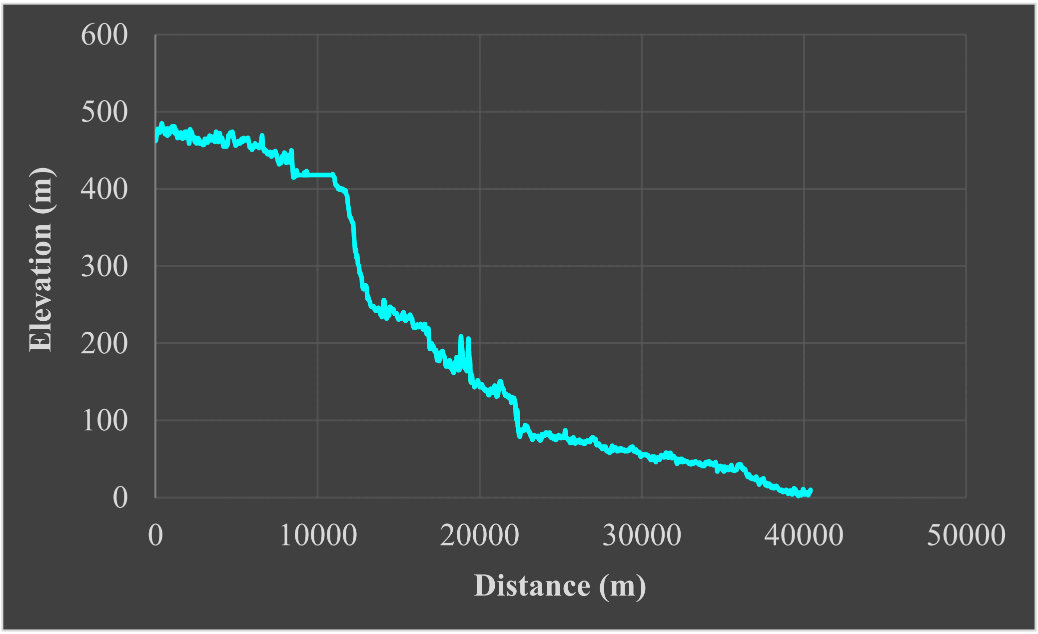


Fig. 4.7. Longitudinal elevation profile of Chalakudy main river

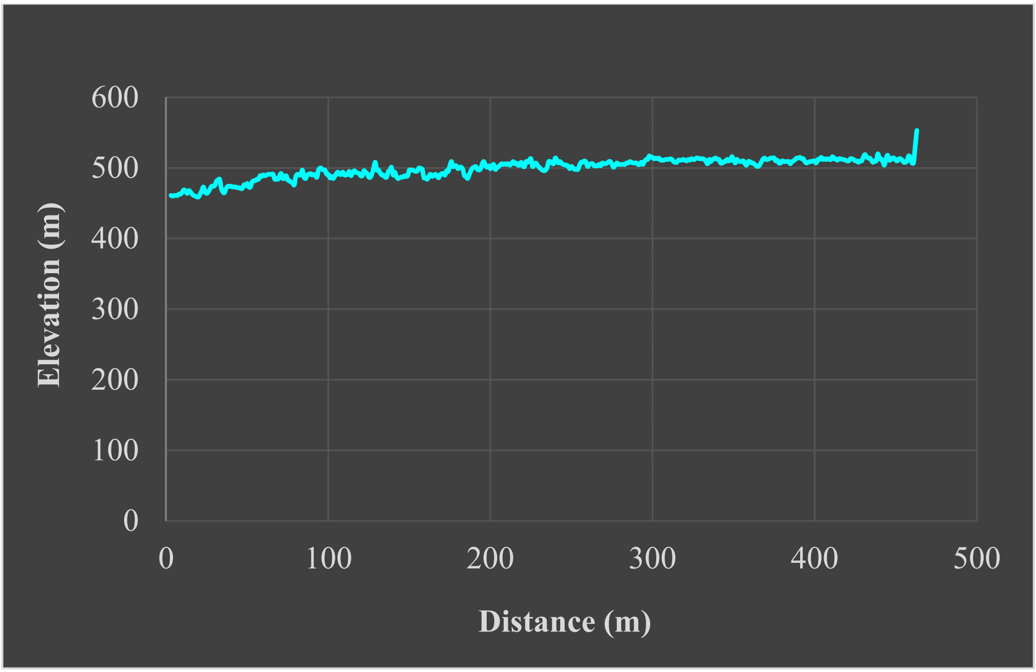


Fig. 4.8. Longitudinal elevation profile of Parambikulam River

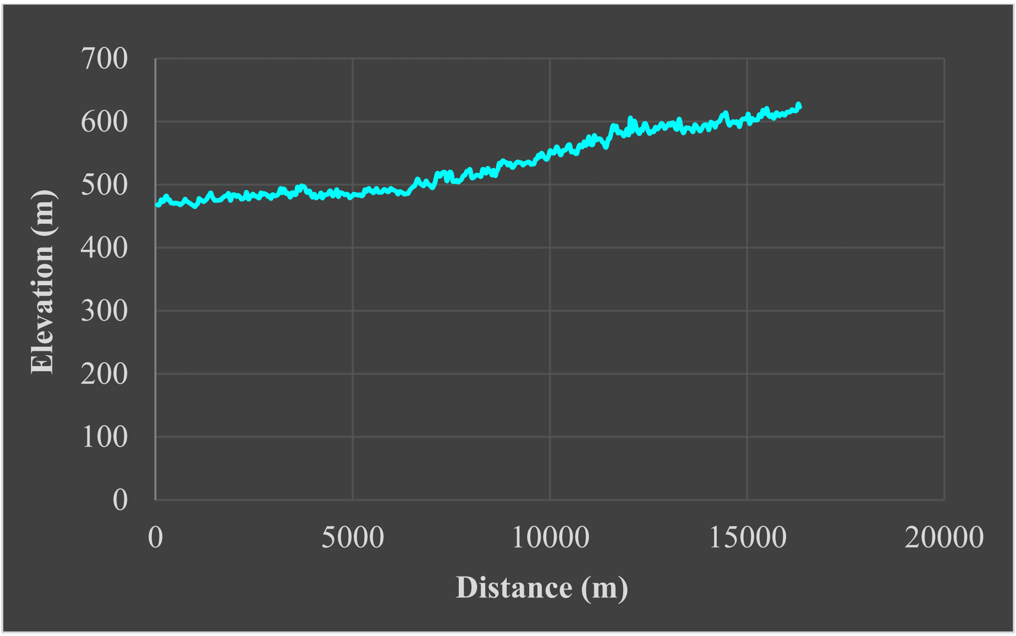


Fig. 4.9. Longitudinal elevation profile of Karappara River

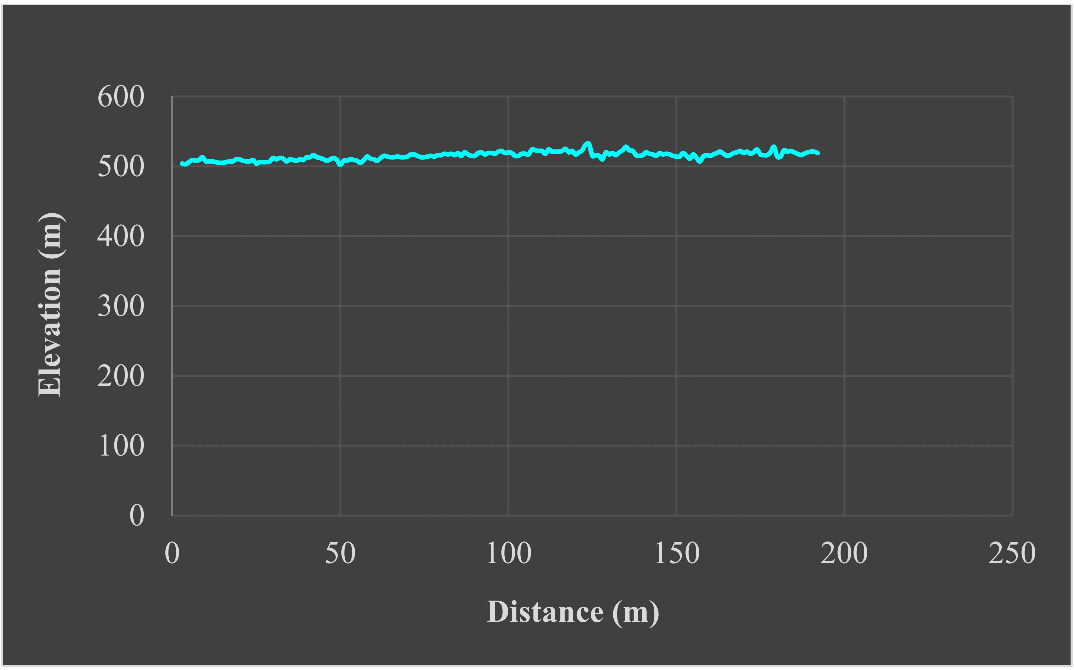


Fig. 4.10. Longitudinal elevation profile of Kuriyarkutty River

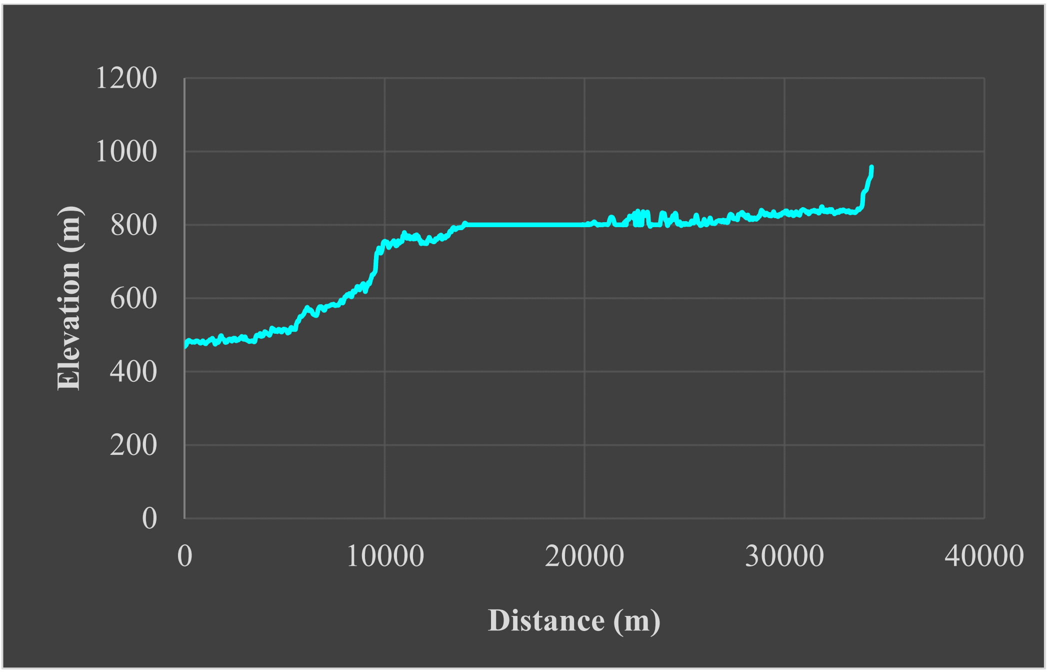


Fig. 4.11. Longitudinal elevation profile of Sholayar River

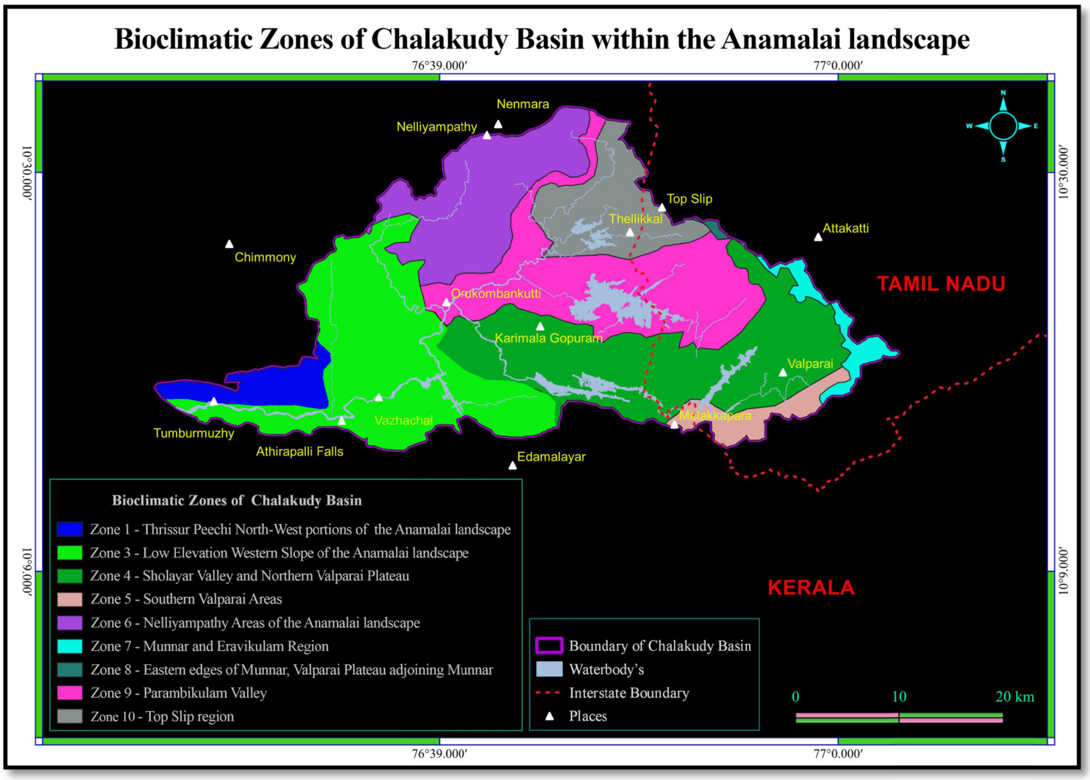


Fig. 4.12. Bioclimatic zones of Chalakudy basin

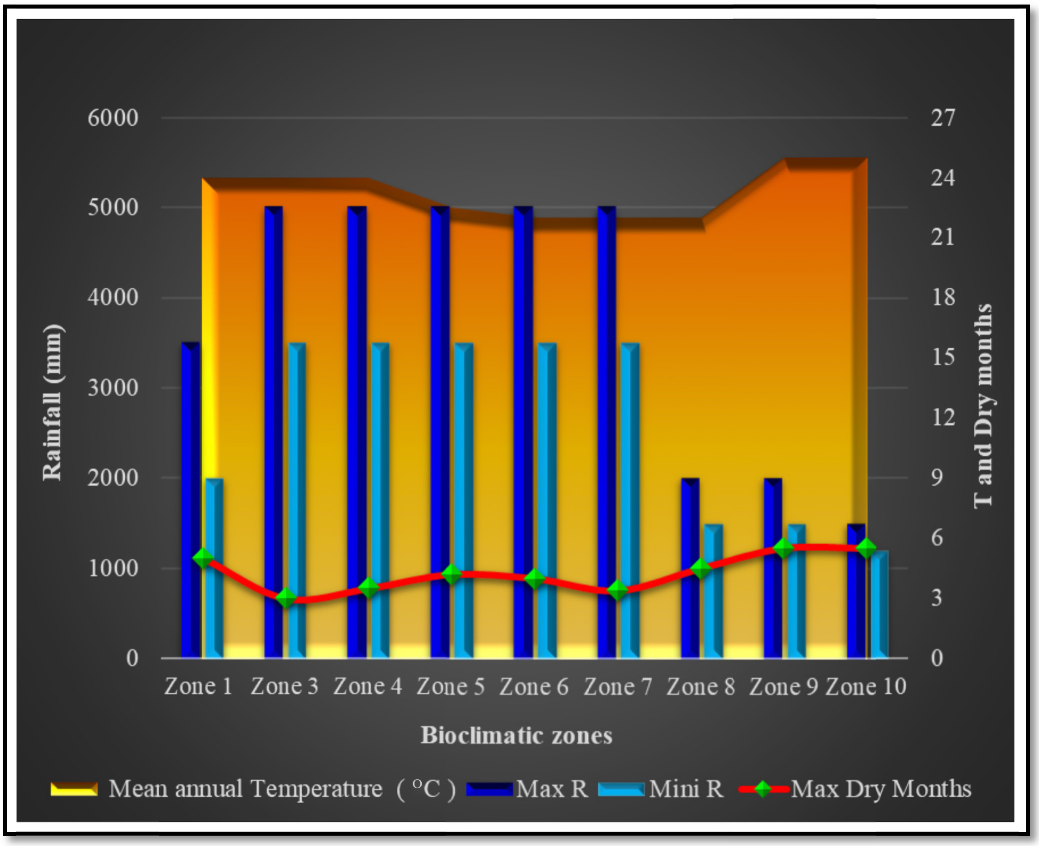


Fig. 4.13. Meteorological data for the identified bioclimatic zones of the Chalakudy basin

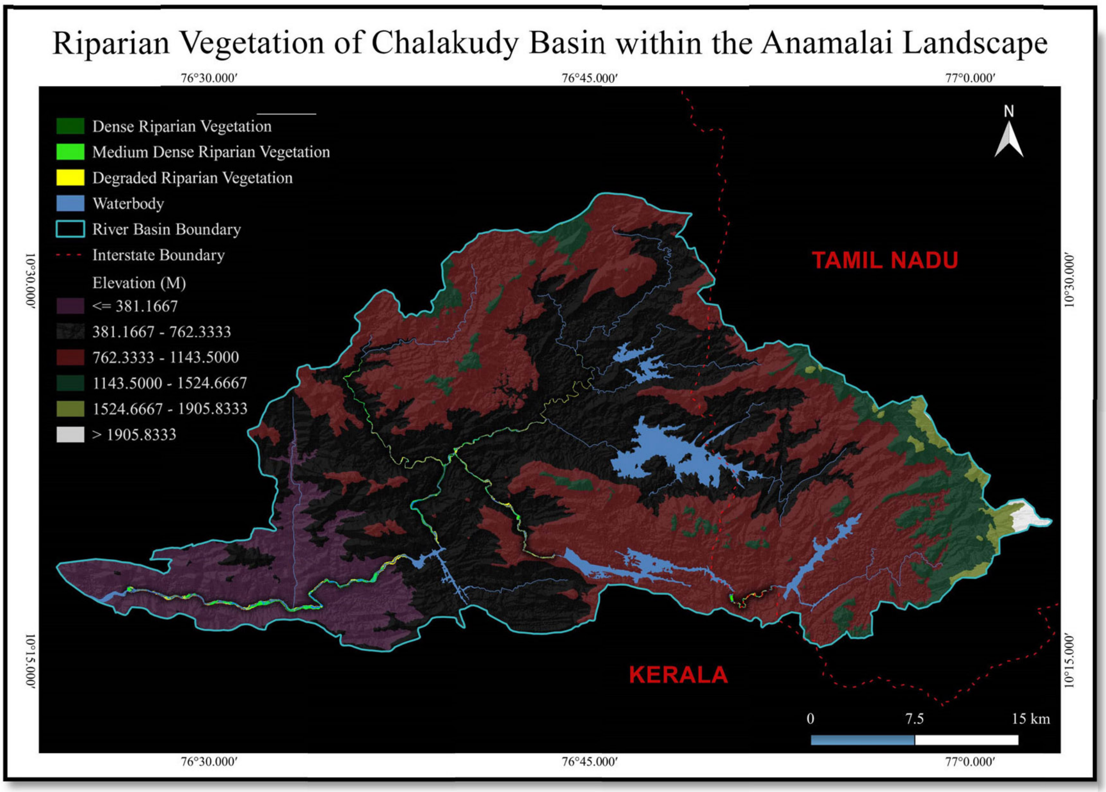


Fig. 4.14. Riparian vegetation of Chalakudy basin

Table 4.3. Riparian vegetation of Chalakudy basin

Sl. No	Vegetation type	Chalakudy Main River (ha)	Sholayar River (ha)	Karappara River (ha)	Kuriyarkutty River (ha)	Parambikulam River (ha)	Total (ha)
1	Dense Riparian Forests	61.57	10.39	8.76	0.00	4.38	85.10
2	Medium dense Riparian Forests	118.50	27.00	14.71	0.00	11.76	171.97
3	Degraded Riparian Forests	96.81	45.92	20.70	7.87	16.22	187.52
Total		276.88	83.31	44.17	7.87	32.36	444.59

The Chalakudy basin's four important tributaries, Sholayar (22.45 km), Karappara (16.61 km), Kuriyarkutty (8.32 km) and Parambikulam (9.61 km), come within the boundary of the Anamalai landscape, with a basin area of 1228 km^2. The Chalakudy River basin represents 9 identified bioclimatic zones (Chapter 3) of the Anamalai landscape (Zone 1- Thrissur Peechi North -West portions of the Anamalai landscape, Zone 3- Low elevation western slope of the Anamalai landscape, Zone 4- Sholayar Valley and Northern Valparai Plateau, Zone 5- Southern Valparai Areas, Zone 6- Nelliyampathy areas of the Anamalai landscape, Zone 7- Munnar and Eravikulam region, Zone 8- Eastern edges of Munnar, Valparai plateau adjoining Munnar, Zone 9-Parambikulam valley and Zone 10- Top slip region). The largest riparian area in the Anamalai landscape is found in the Chalakudy basin (444.59 ha.), which covers 63.77 % of the entire riparian forest of the Anamalai landscape unit. Also, the Chalakudy basin has the highest dense riparian forest cover, 85.10 ha (19.14 %), medium-dense riparian forest covers 171.97 ha (38.68 %), and Degraded riparian forests comprised (187.52 ha) 42.18 %.

4.3.c.ii. Periyar basin within the Anamalai landscape

- **Longitudinal elevation profiles and bioclimate of the Periyar River basin**

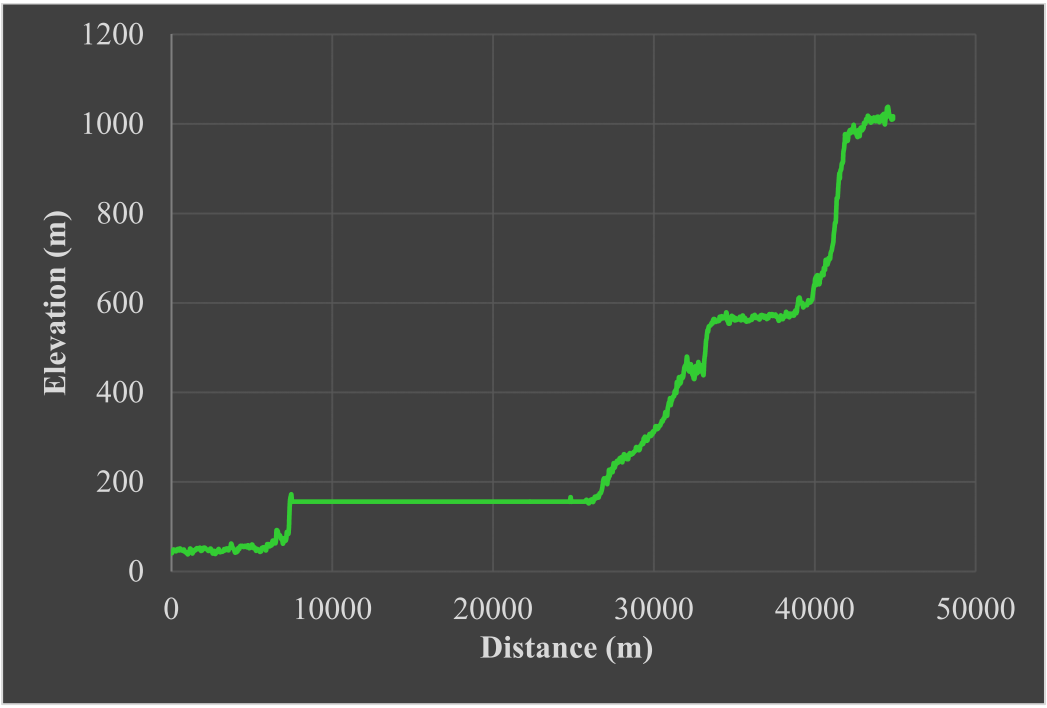


Fig. 4.15. Longitudinal elevation profile of Idamalayar River

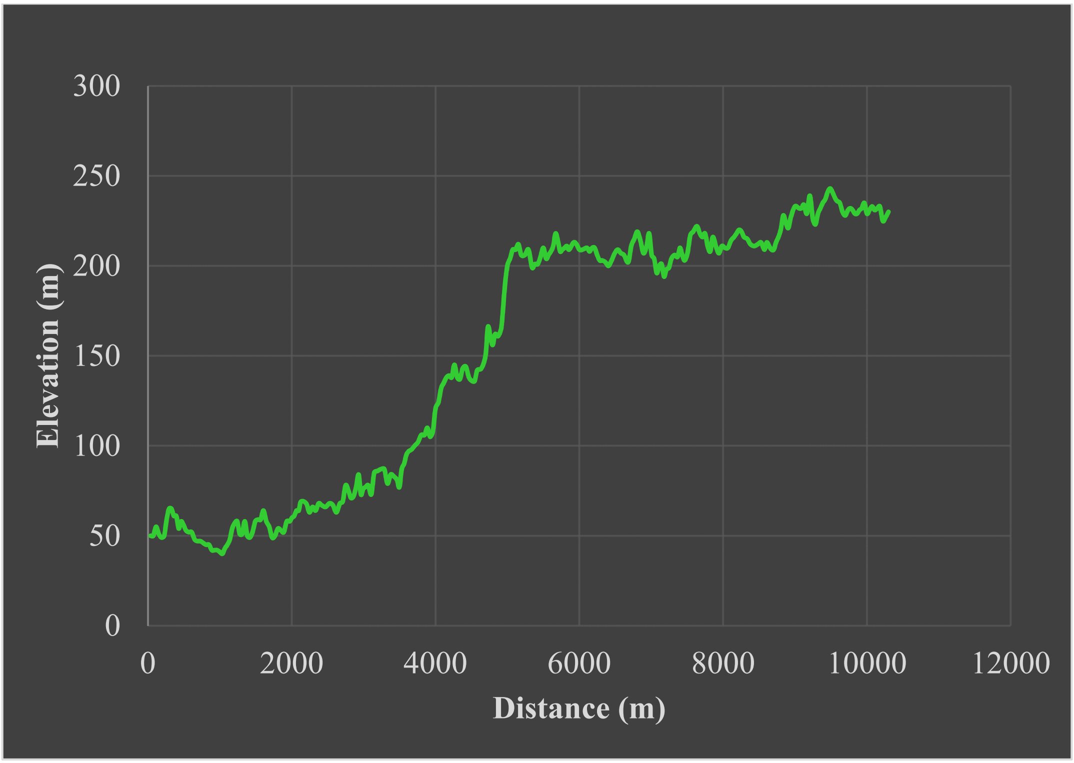


Fig. 4.16. Longitudinal elevation profile of Pooyamkutty River

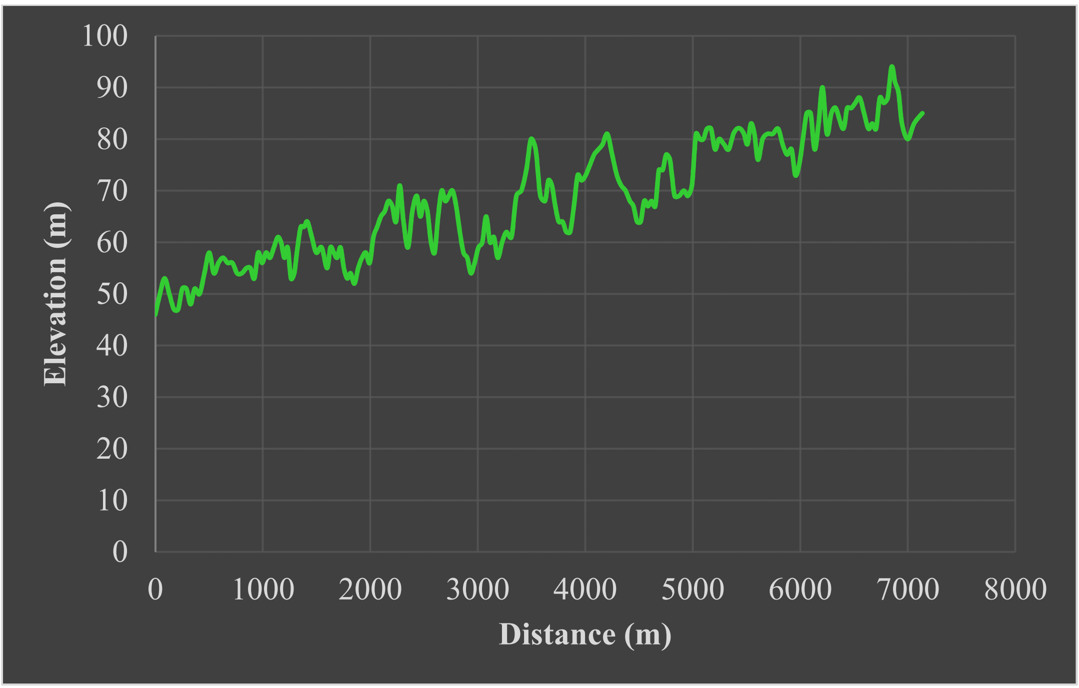


Fig. 4.17. Longitudinal elevation profile of Pichi Ar

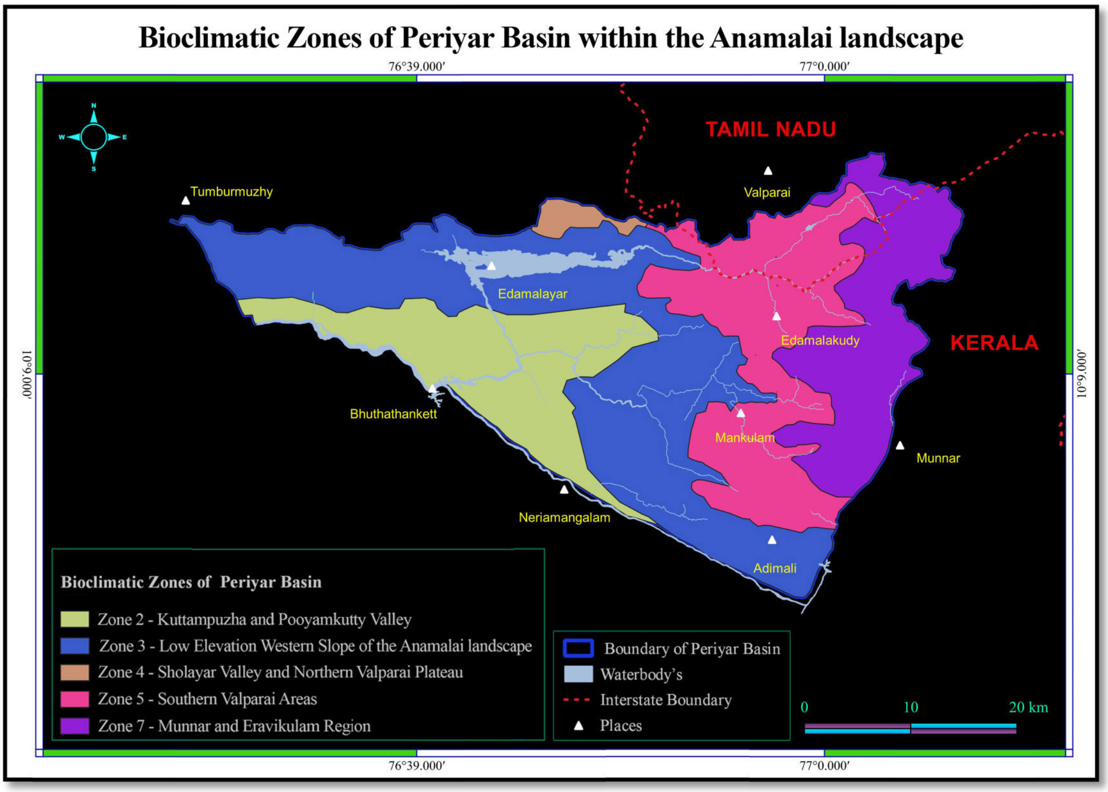


Fig. 4.18. Bioclimatic zones of Periyar basin

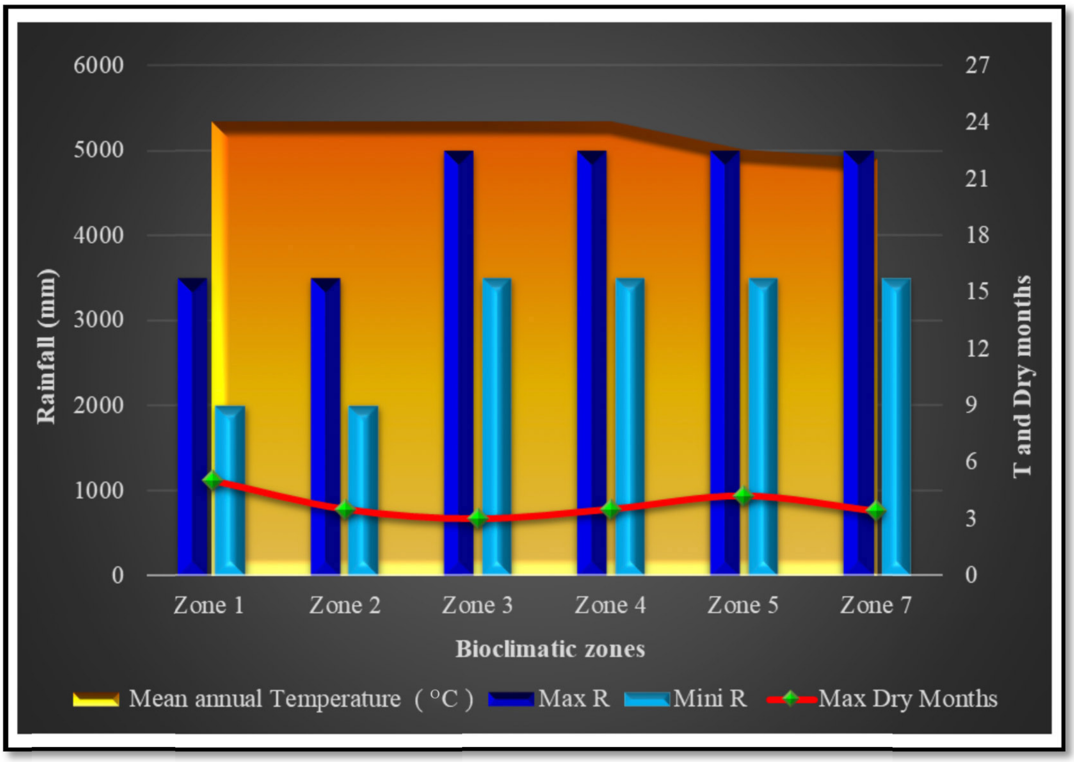


Fig. 4.19. Meteorological data for the identified bioclimatic zones of the Periyar basin

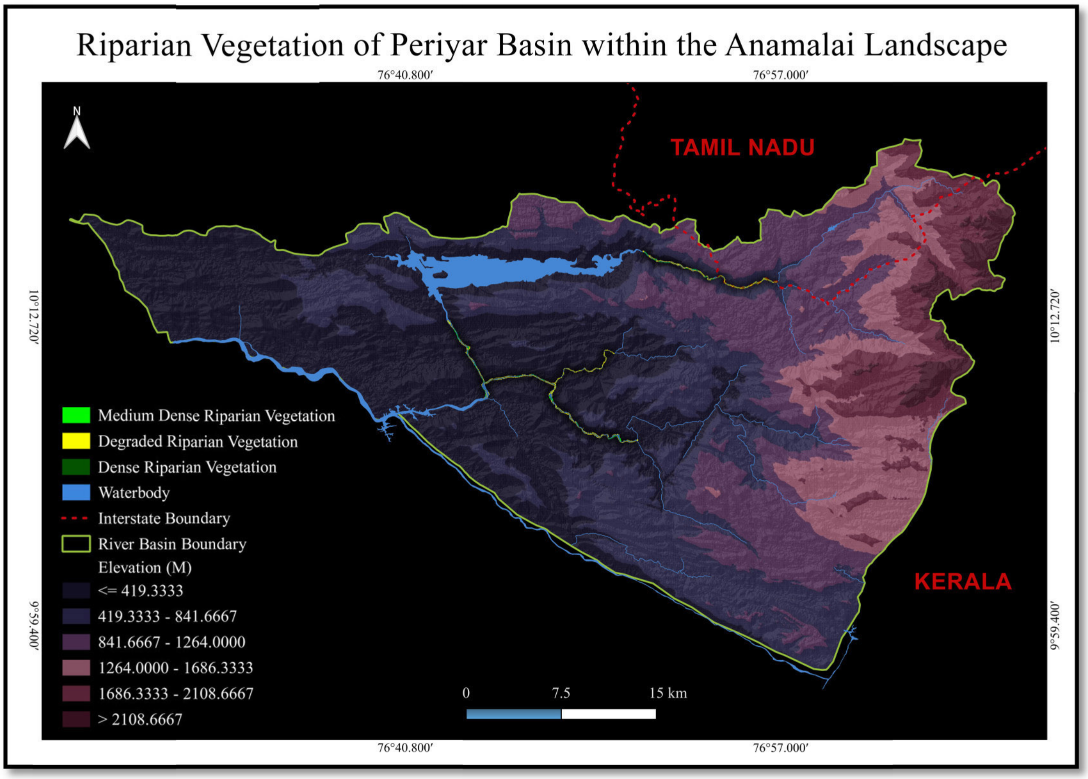


Fig. 4.20. Riparian vegetation of Periyar basin

Table 4.4. Riparian vegetation of Periyar basin

Sl. No.	Vegetation Type	Idamalayar River (ha)	Pooyamkutty River (ha)	Pichi Ar (ha)	Total (ha)
1	Dense Riparian Forests	3.39	0.00	0.00	3.39
2	Medium dense Riparian Forests	16.80	10.30	0.00	27.10
3	Degraded Riparian Forests	39.59	44.18	9.13	92.90
Total		59.79	54.48	9.13	123.39

Periyar River basin, with an area of 1465 km2, has three tributaries (Idamalayar, Pooyamkutty and Pichi Ar, with 24.16 km, 16.37 km and 7.32 km, respectively) inside the Anamalai landscape. Periyar Basin represents six bioclimatic zones of the Anamalai landscape: Zone 1- Thrissur Peechi North -West portions of the Anamalai landscape, Zone 2-Kuttampuzha and Pooyamkutty Valley, Zone 3- Low elevation western slope of the Anamalai landscape, Zone 4- Sholayar Valley and Northern Valparai Plateau, Zone 5- Southern Valparai Areas and Zone 7- Munnar and Eravikulam region. The overall extent of riparian forest distribution in the Periyar basin within the Anamalai landscape is 123.39 ha. Here, dense riparian forests cover 3.39 ha (2.75 %), medium-dense riparian forests cover 27.10 ha (21.97%), and degraded riparian forests cover 92.90 ha (75.29 %).

4.3.c.iii. Karuvannur basin within the Anamalai landscape

- **Longitudinal elevation profiles and bioclimate of the Karuvannur River basin**

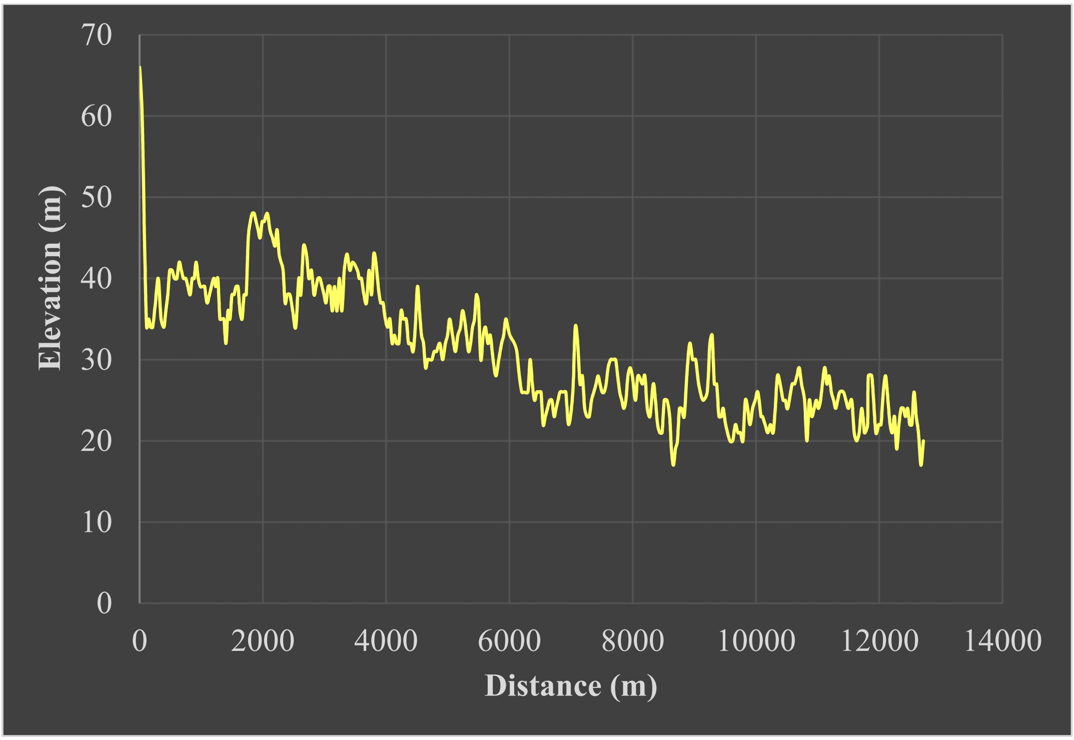


Fig. 4.21. Longitudinal elevation profile of Chimmony River

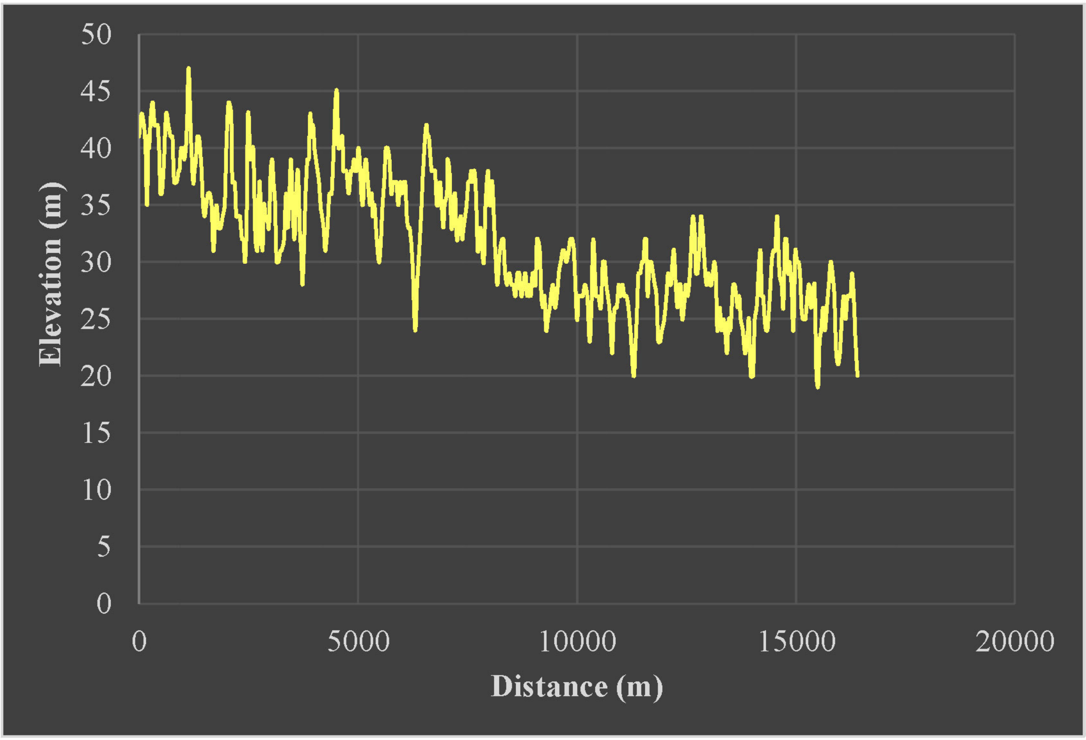


Fig. 4.22. Longitudinal elevation profile of Mupli River

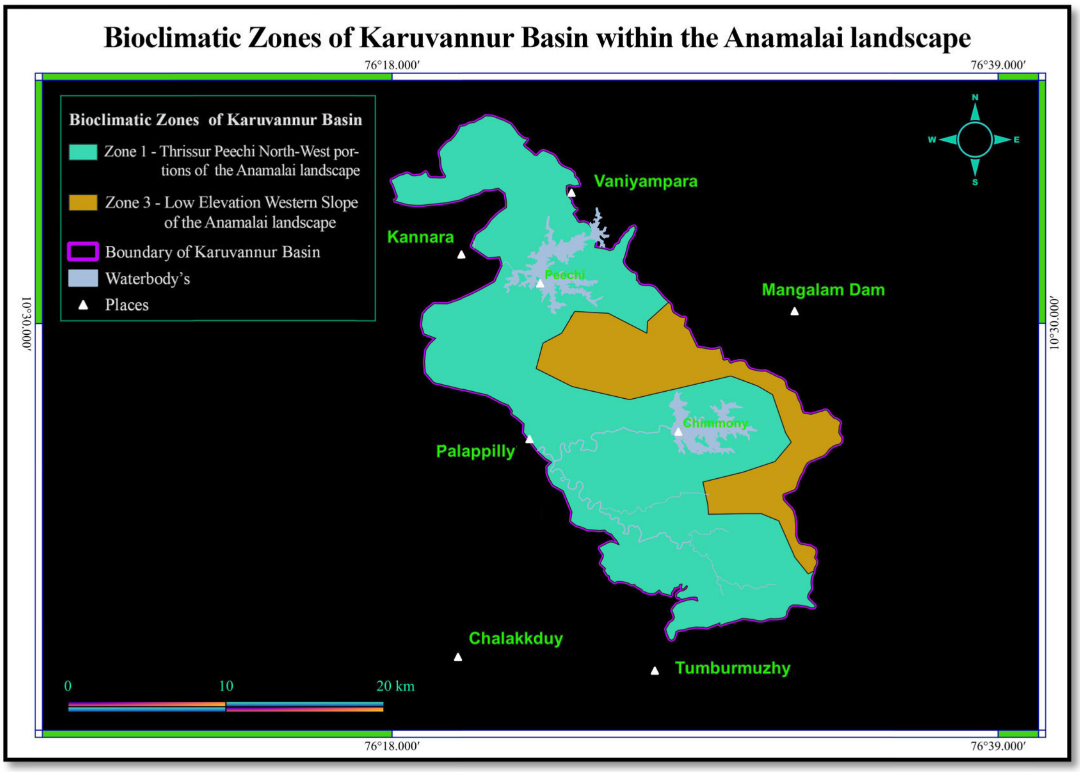


Fig. 4.23. Bioclimatic zones within the Karuvannur basin

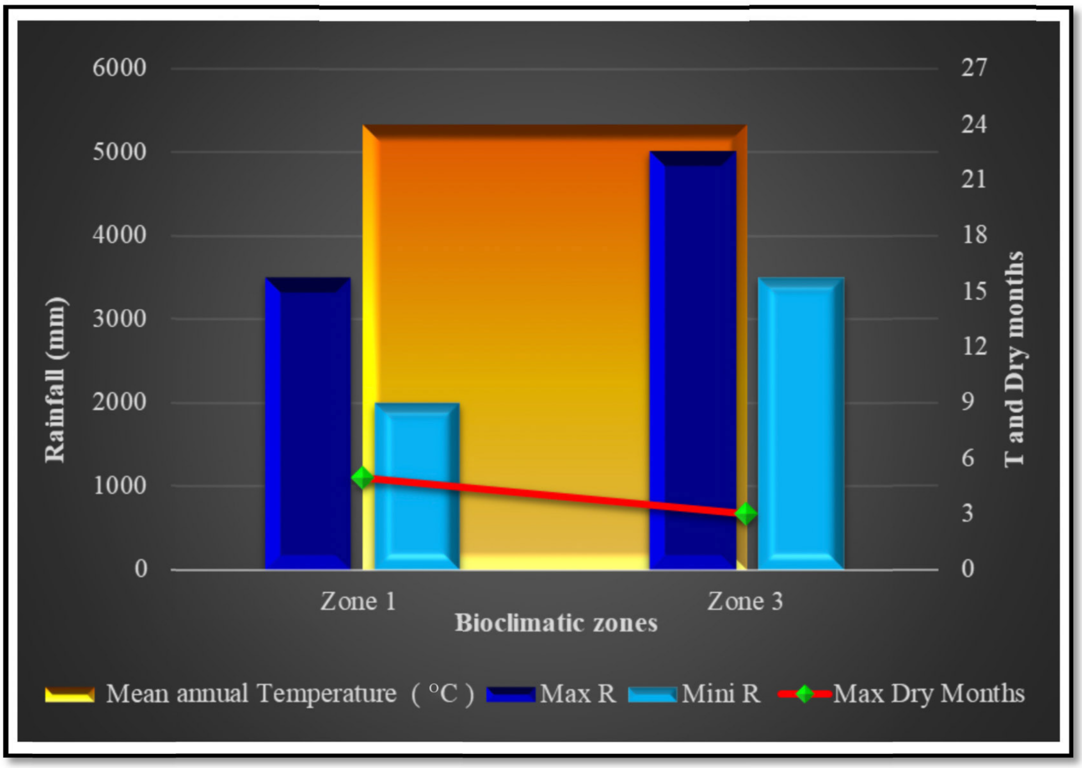


Fig. 4.24. Meteorological data for the identified bioclimatic zones of Karuvannur basin

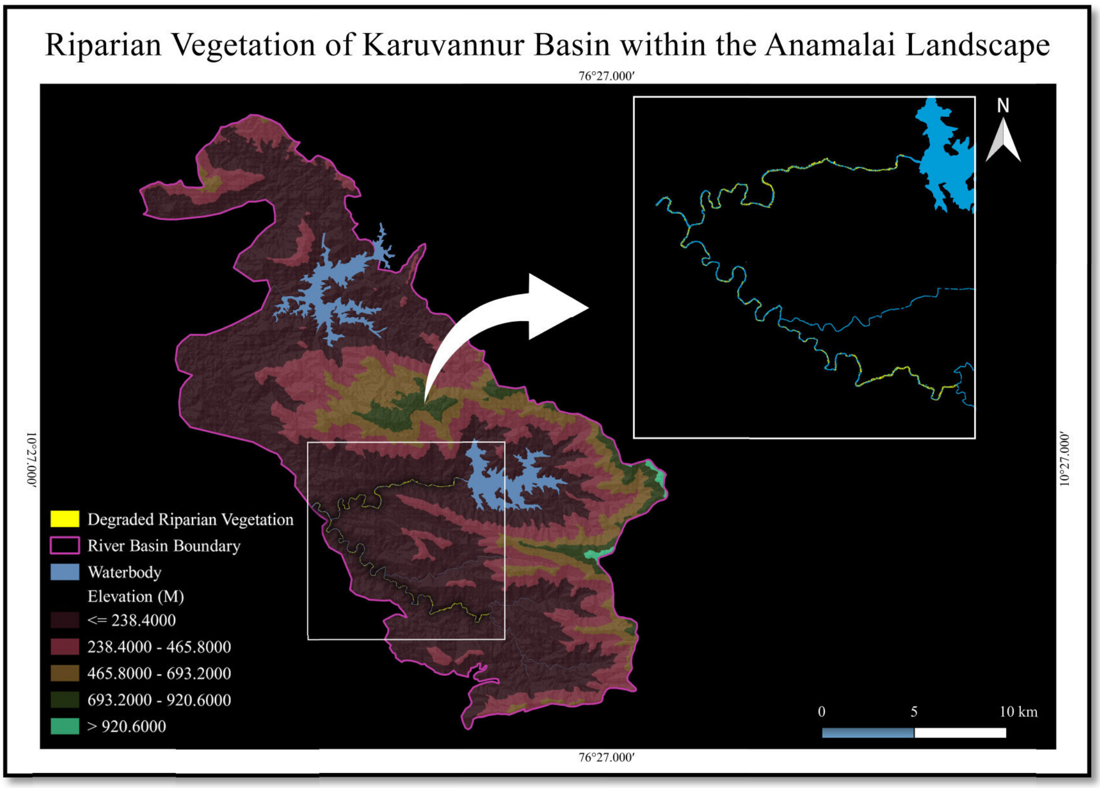


Fig. 4.25. Riparian vegetation of Karuvannur basin

Table 4.5. Riparian vegetation of Karuvannur basin

Sl. No.	Vegetation Type	Chimmony River (ha)	Mupli River (ha)	Total (ha)
1	Dense Riparian Forests	0.00	0.00	0.00
2	Medium dense Riparian Forests	0.00	0.00	0.00
3	Degraded Riparian Forests	11.17	12.24	23.41
Total		11.17	12.24	23.41

Karuvannur River basin (411.28 km2) has two tributaries within the Anamalai landscape, which include Chimmony (14.72 km) and Mupli (18.96 km). It covers only two bioclimatic zones: Zone 1- Thrissur Peechi North -West portions of the Anamalai landscape and Zone 3- Low elevation western slope of the Anamalai landscape. The total riparian forest area in the Karuvannur basin within the Anamalai landscape is 23.41 ha and degraded. This is found along the riparian zones of the two tributaries of the Karuvannur basin, the Chimmony (11.17 ha.) and Mupli Rivers (12.24 ha.).

4.3.c. iv. Bharathapuzha basin within the Anamalai landscape

- **Longitudinal elevation profiles and bioclimate of the Bharathapuzha River basin**

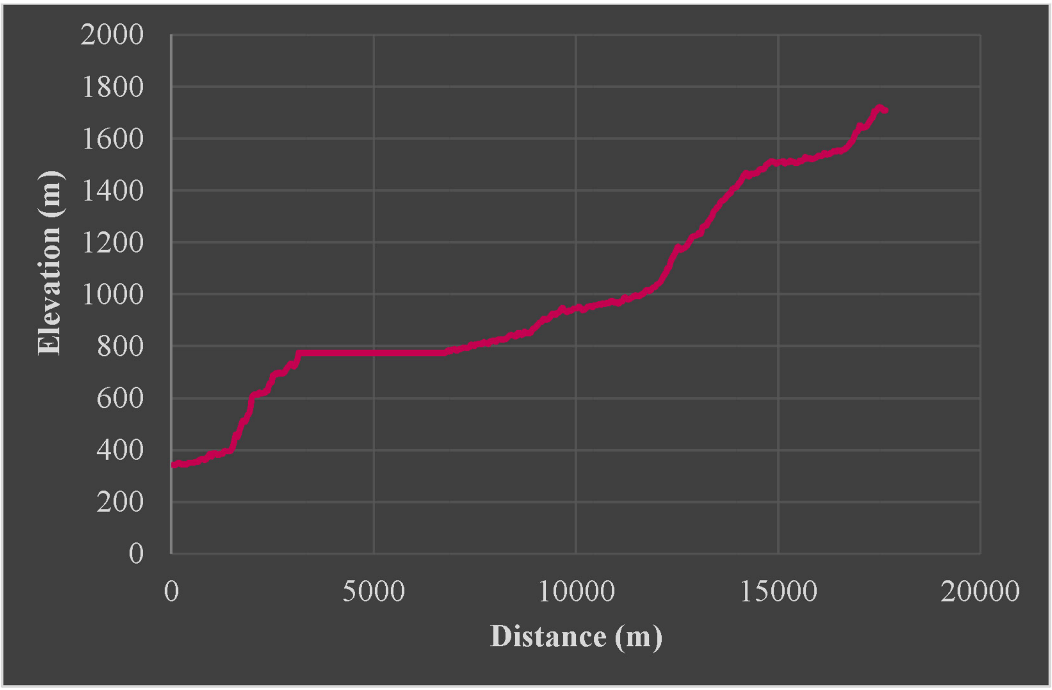


Fig. 4.26. Longitudinal elevation profile of Aliyar River

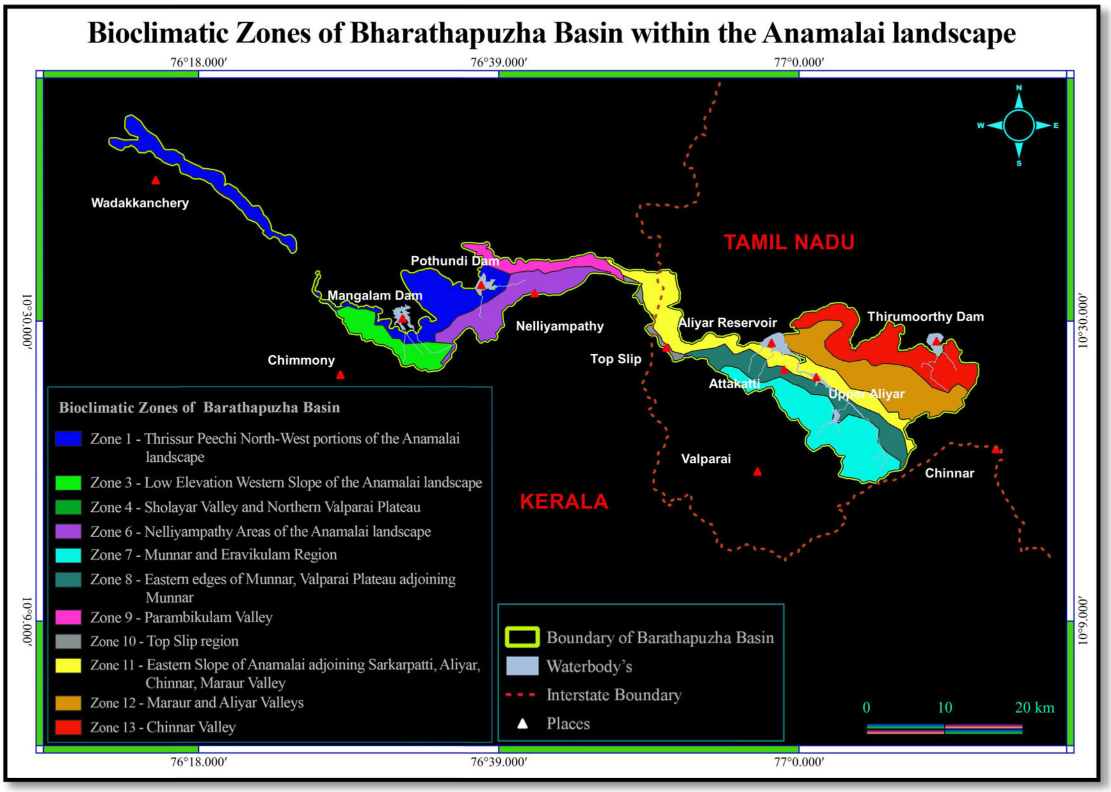


Fig. 4.27. Bioclimatic zones within the Bharathapuzha basin

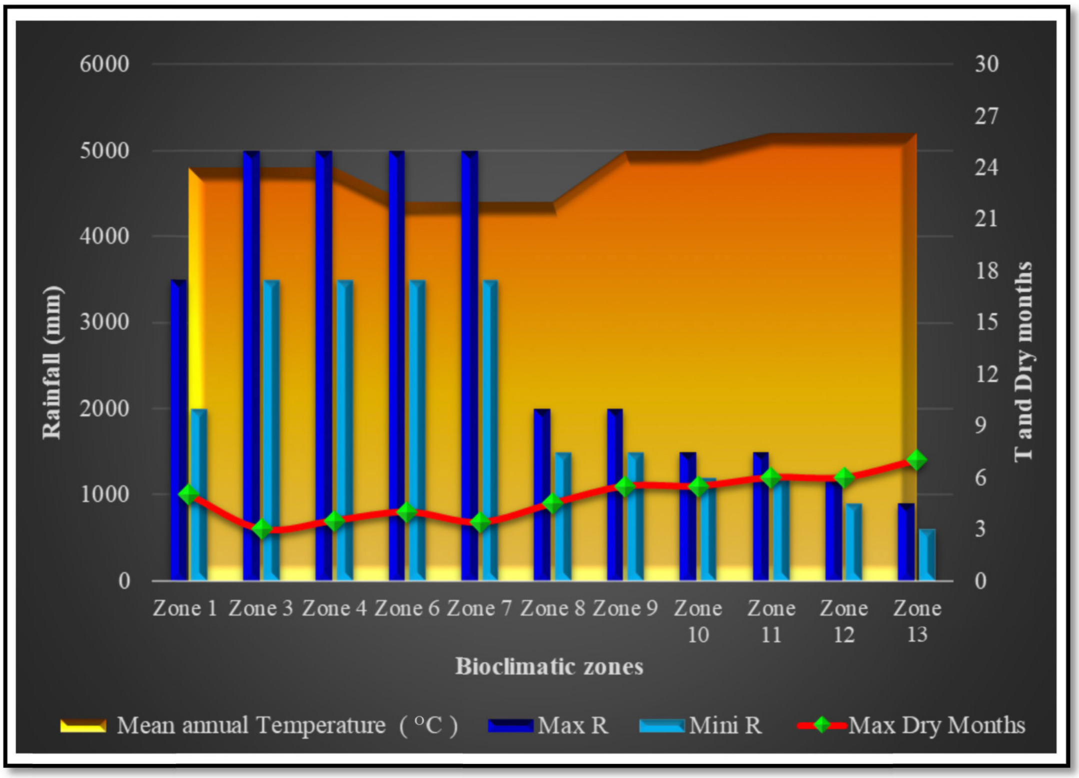


Fig. 4.28. Meteorological data for the identified bioclimatic zones of Bharathapuzha basin

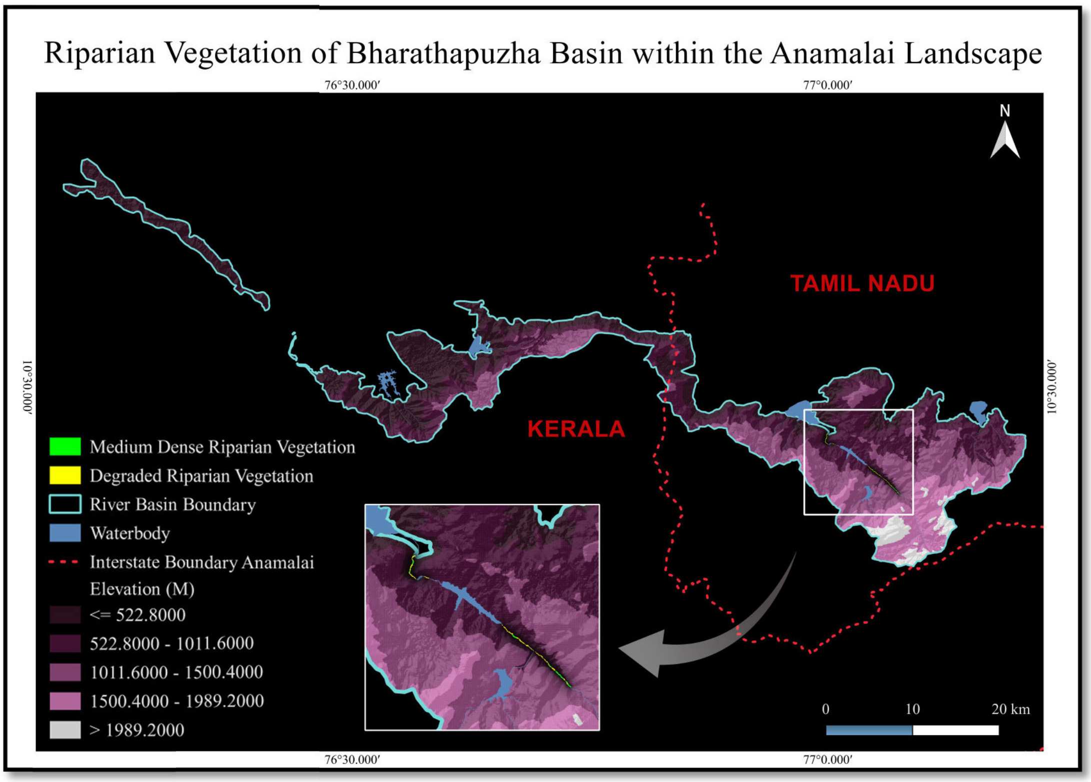


Fig. 4.29. Riparian vegetation of Bharathapuzha basin

Table 4.6. Riparian vegetation of Bharathapuzha basin

Sl. No.	Vegetation Type	Aliyar River (ha)	Total (ha)
1	Dense Riparian Forests	0.00	0.00
2	Medium dense Riparian Forests	5.47	5.47
3	Degraded Riparian Forests	7.84	7.84
Total		13.31	13.31

Aliyar River is the only tributary of the Bharathapuzha basin, is located inside the Anamalai landscape boundary, measuring 9.59 km in length, the basin covers an area of 679.25 km^2. And the basin has 11 different bioclimatic zones: Zone 1- Thrissur Peechi North -West portions of the Anamalai landscape, Zone 3- Low elevation western slope of the Anamalai landscape, Zone 4- Sholayar Valley and Northern Valparai Plateau, Zone 6- Nelliyampathy areas of the Anamalai landscape, Zone 7- Munnar and Eravikulam region, Zone 8- Eastern edges of Munnar, Valparai plateau adjoining Munnar, Zone 9-Parambikulam valley, Zone 10- Top slip region, Zone 11- Eastern slope of the Anamalai landscape adjoining Sarkarpatti, Aliyar, Chinnar and Maraur Valley, Zone 12- Maraur and Aliyar valleys and Zone 13- Chinnar valley. 13.31 ha of riparian forests are present along the Aliyar tributary in the Bharathapuzha basin. Which is represented by 5.47 ha contained Medium dense riparian forests (41.07 %), degraded riparian forests 7.84 ha (58.93 %), and representation of dense riparian forests not found in the riparian areas of the Aliyar tributary.

4.3.c.v. Pambar basin within the Anamalai landscape

- **Longitudinal elevation profiles and bioclimate of the Pambar River basin**

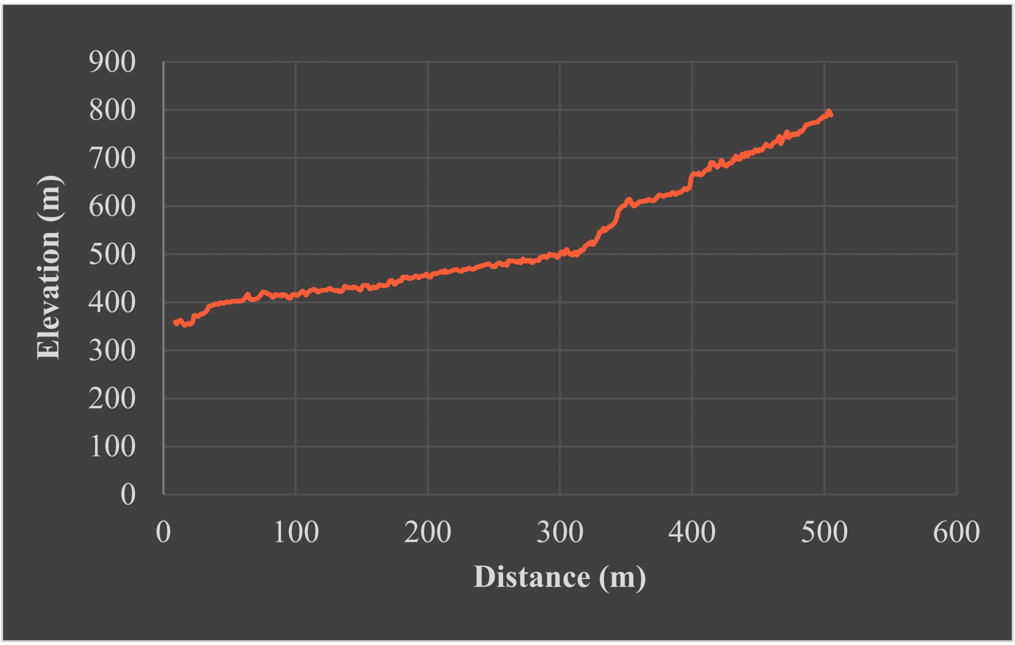


Fig. 4.30. Longitudinal elevation profile of Pambar River

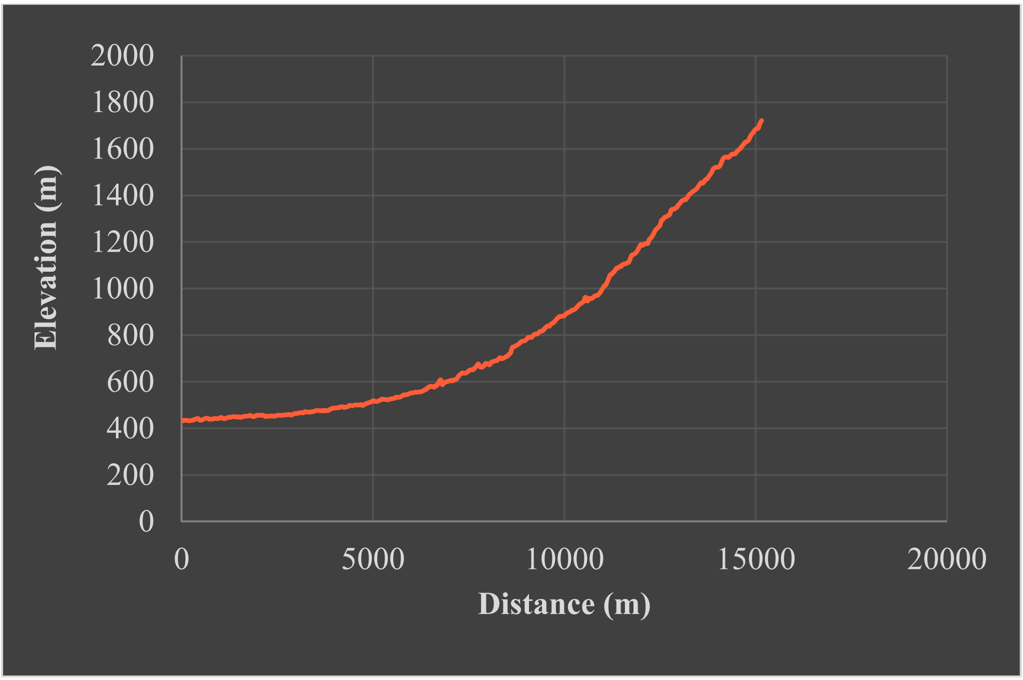


Fig. 4.31. Longitudinal elevation profile of Chinnar River

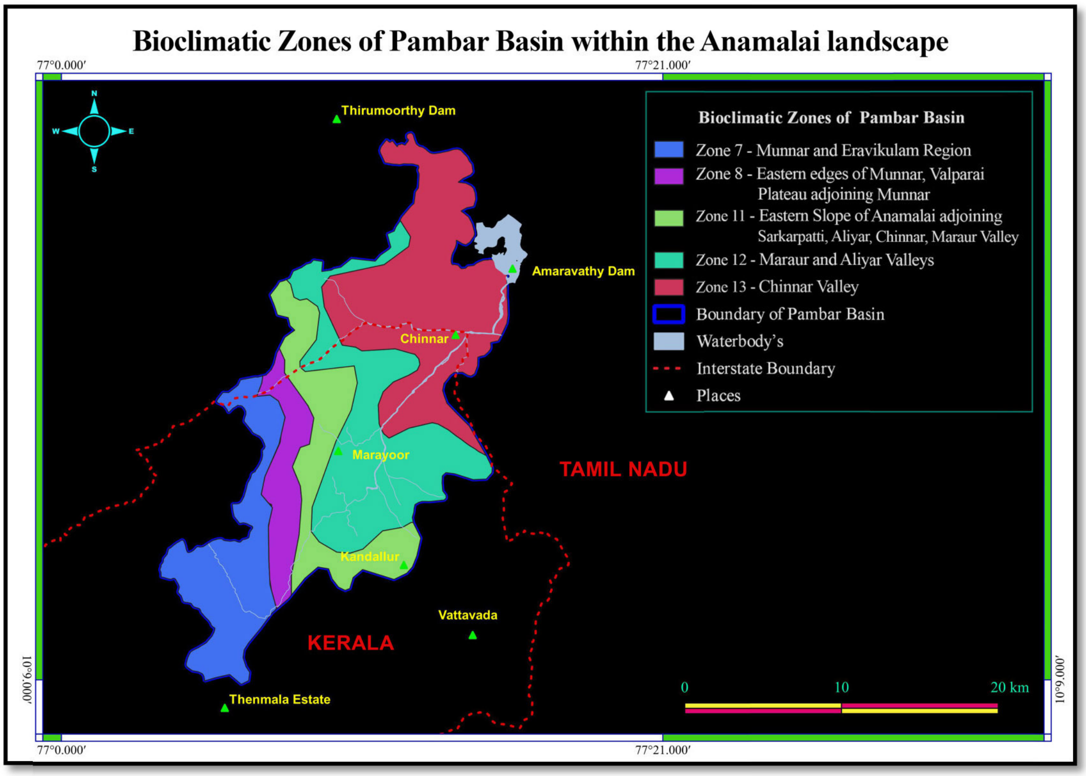


Fig. 4.32. Bioclimatic zones within the Pambar basin

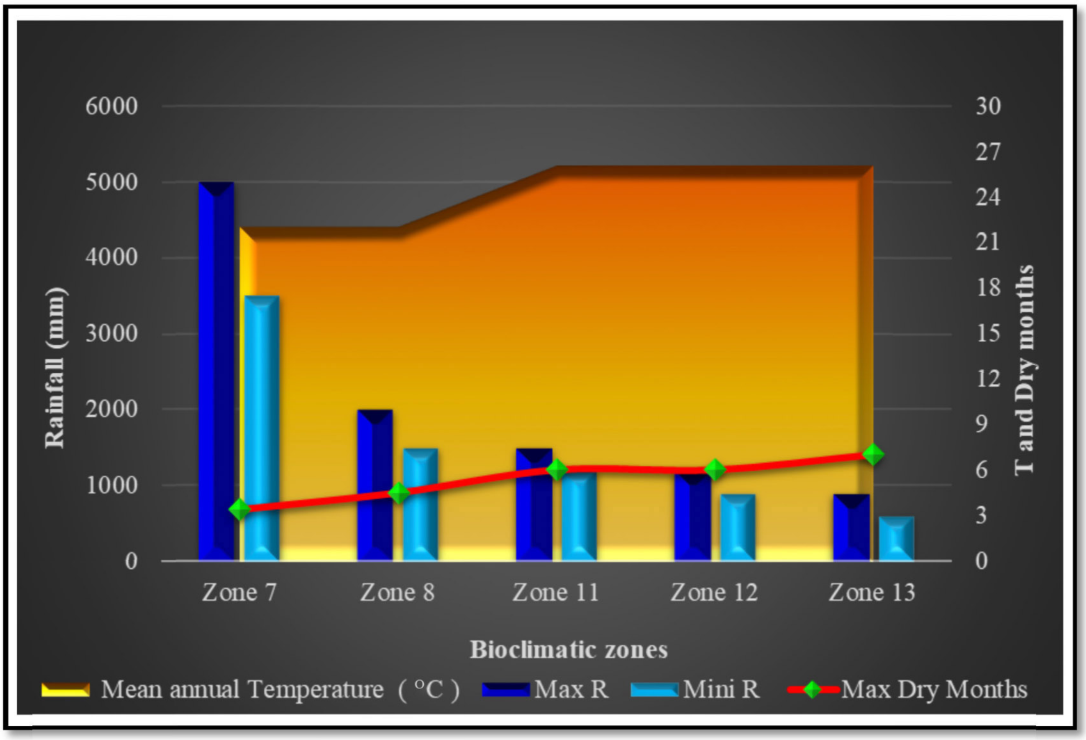


Fig. 4.33. Meteorological data for the identified bioclimatic zones of the Pambar basin

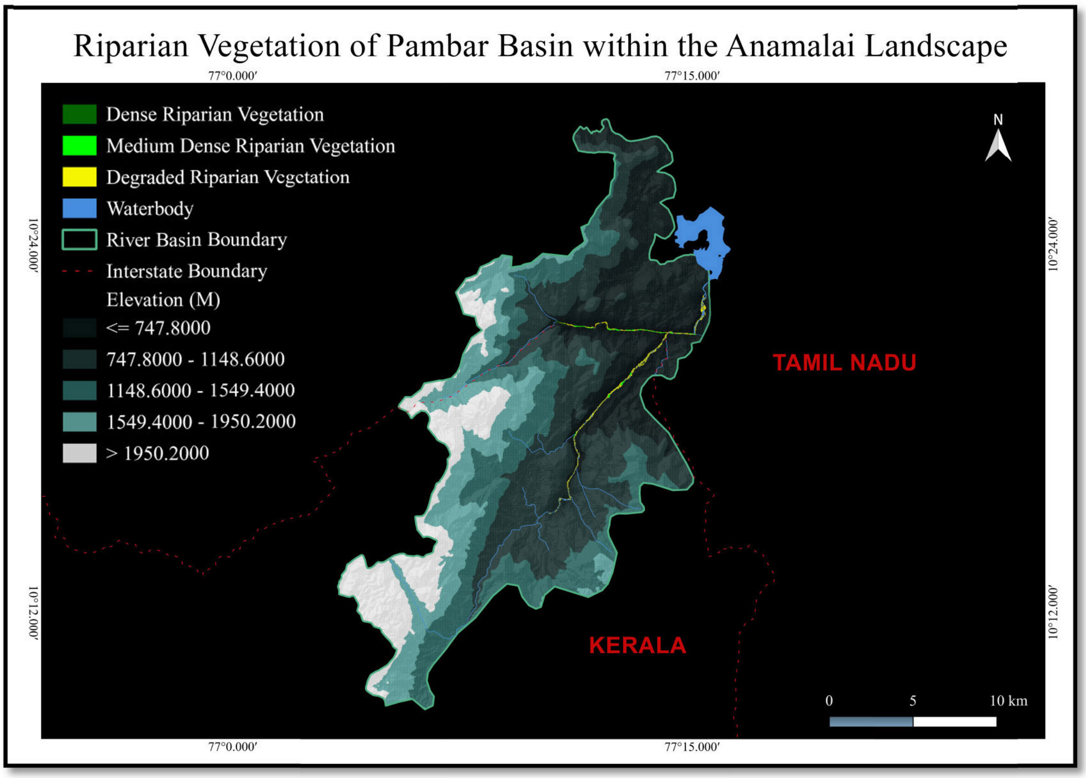


Fig. 4.34. Riparian vegetation of the Pambar basin

Table 4.7. Riparian vegetation of Pambar basin

Sl. No.	Vegetation Type	Chinnar River (up to Kootar) (ha)	Pambar River (up to Amaravathy Reservoir) (ha)	Total (ha)
1	Dense Riparian Forests	3.30	0.00	3.30
2	Medium-dense Riparian Forests	11.31	7.20	18.51
3	Degraded Riparian Forests	11.96	58.60	70.56
	Total	26.57	65.80	92.37

The Chinnar River main stream portion (7.26 km) and the Pambar main River (19.02 km), together with a basin area of 338.3 km2, form the Pambar River basin within the Anamalai landscape. The basin is represented by the bioclimatic zones, Zone 7- Munnar and Eravikulam region, Zone 8- Eastern edges of Munnar, Valparai plateau adjoining Munnar, Zone 11- Eastern slope of the Anamalai landscape adjoining Sarkarpatti, Aliyar, Chinnar and Maraur Valley, Zone 12- Maraur and Aliyar valleys and Zone 13-Chinnar valley. The basin covers 92.37 ha of riparian forests, of which 3.30 ha (3.57 %) of dense riparian forests were identified in the upstream portions of each river (Chinnar and Pambar). Medium-dense riparian forests cover 18.51 ha (20.04 %), which are found in areas where the rivers flow through the Chinnar Wild Life Sanctuary. Degraded riparian forests cover 70.56 ha. (76.39 %) along the river's lower regions, and the degradation worsens as it approaches the Amaravathy reservoir.

4.3.c.vi. Kechery basin within the Anamalai landscape

- **Longitudinal elevation profiles and bioclimate of the Kechery River basin**

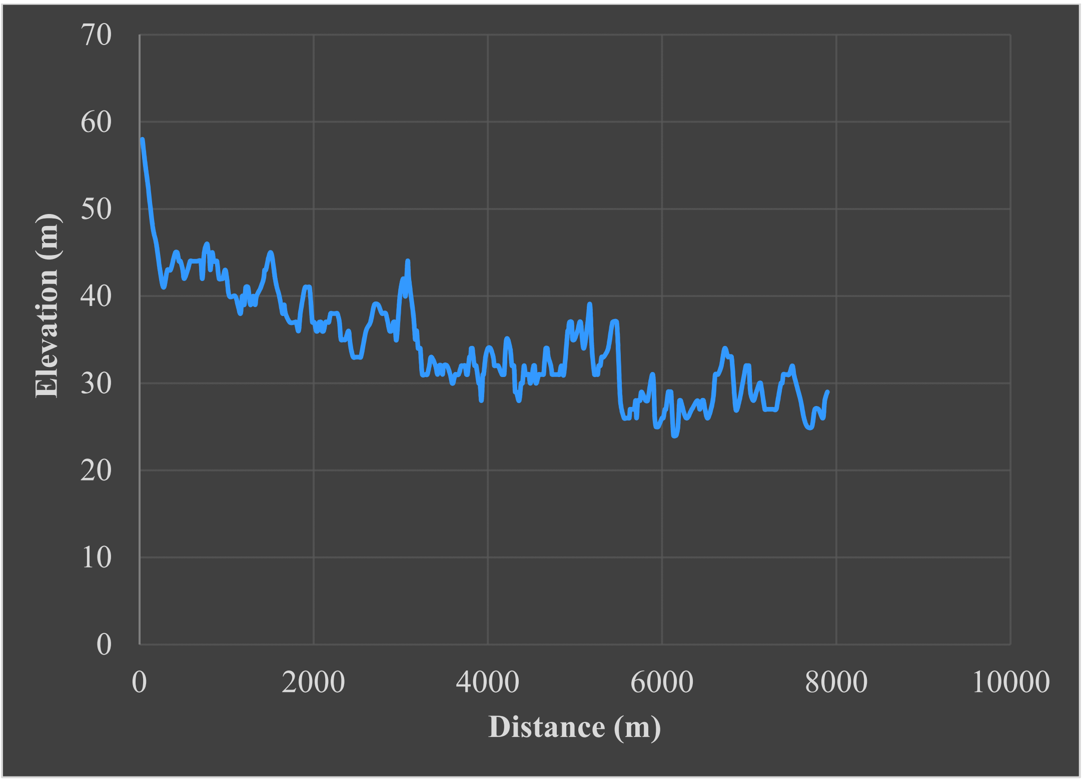


Fig. 4.35. Longitudinal elevation profile of Kechery River

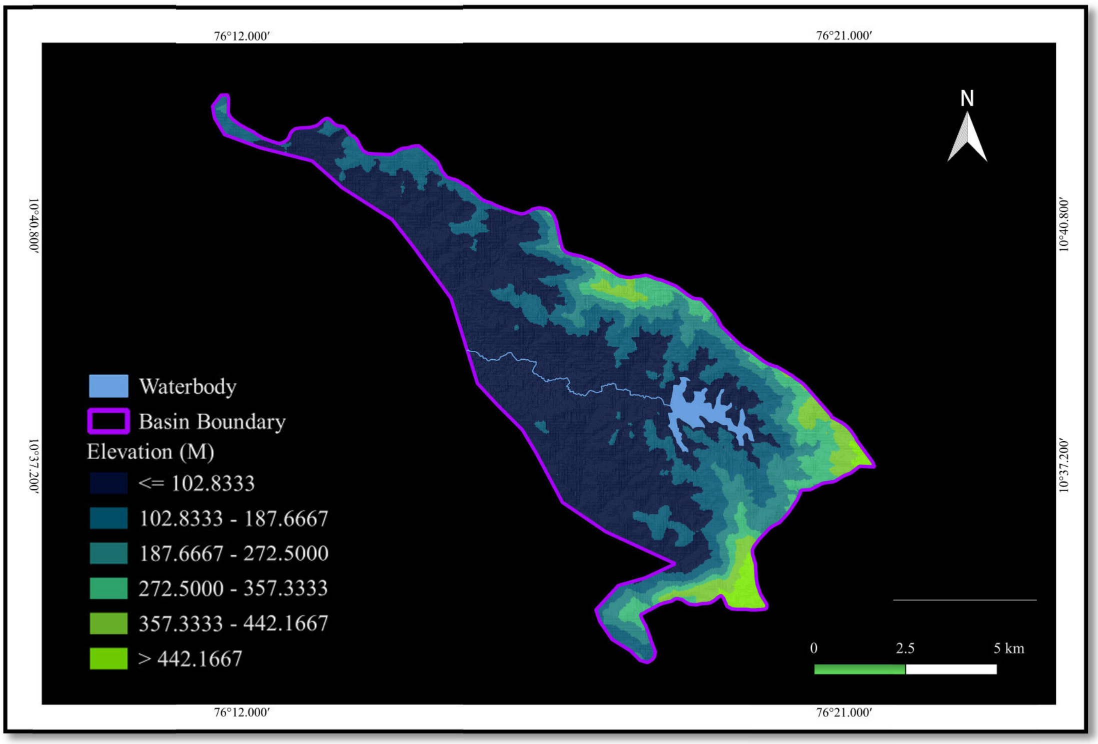


Fig. 4.36. Elevation profile of Kechery basin

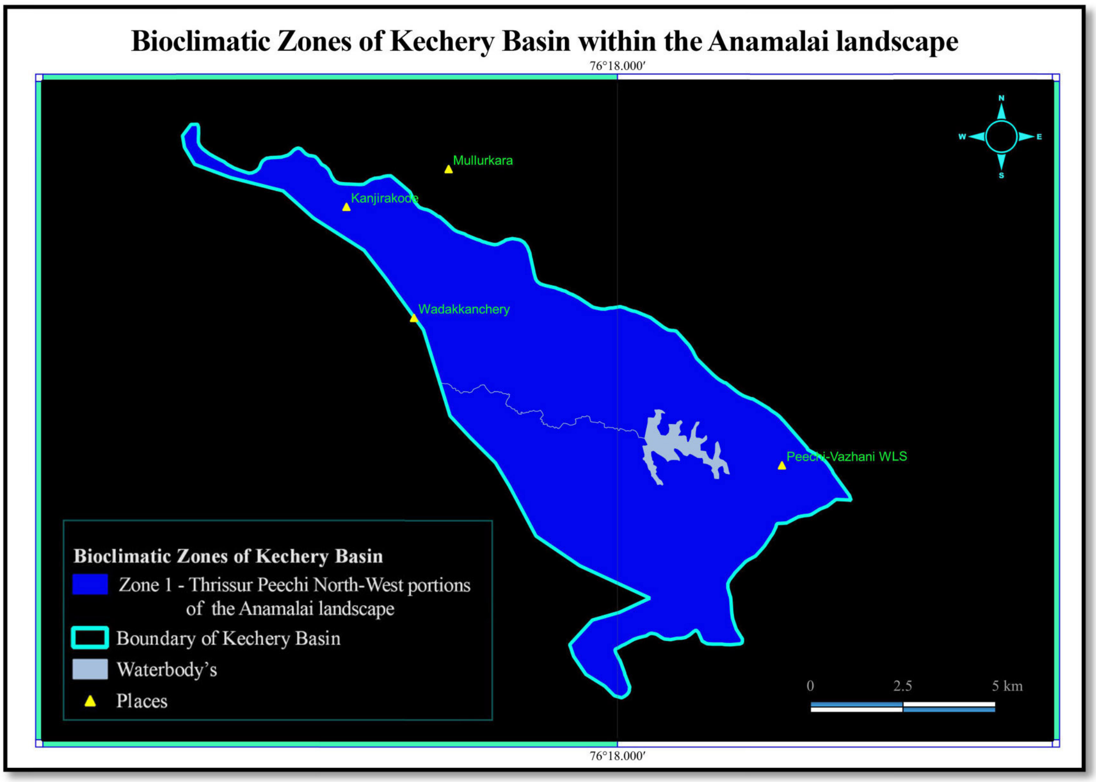


Fig. 4.37. Bioclimatic zones within the Kechery basin

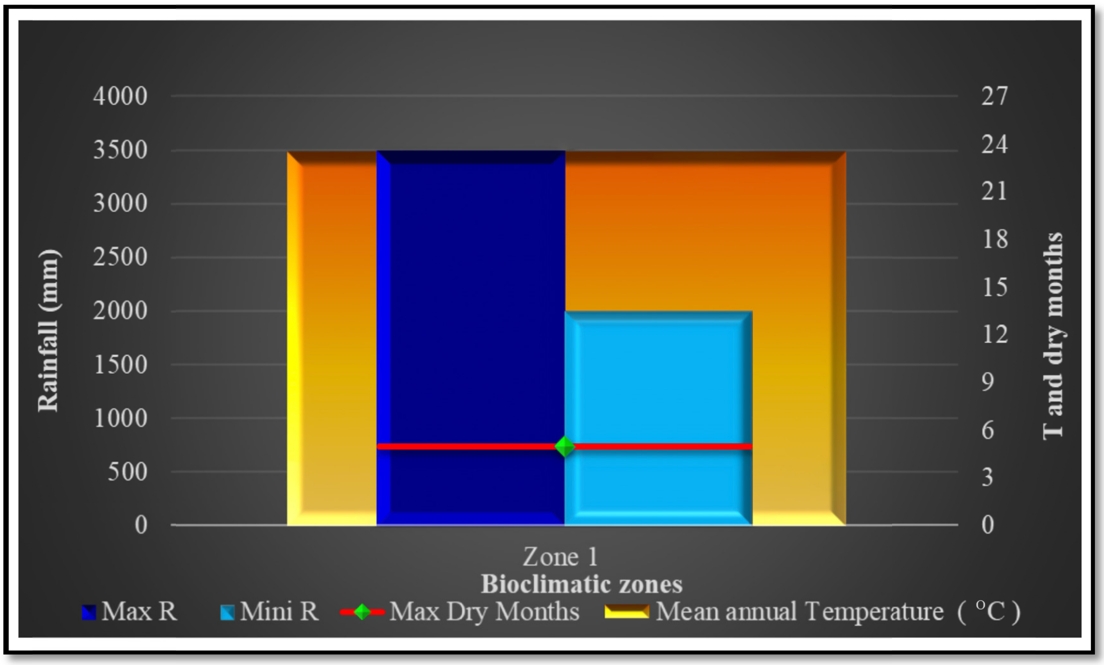


Fig. 4.38. Meteorological data for the identified bioclimatic zones of the Kechery basin

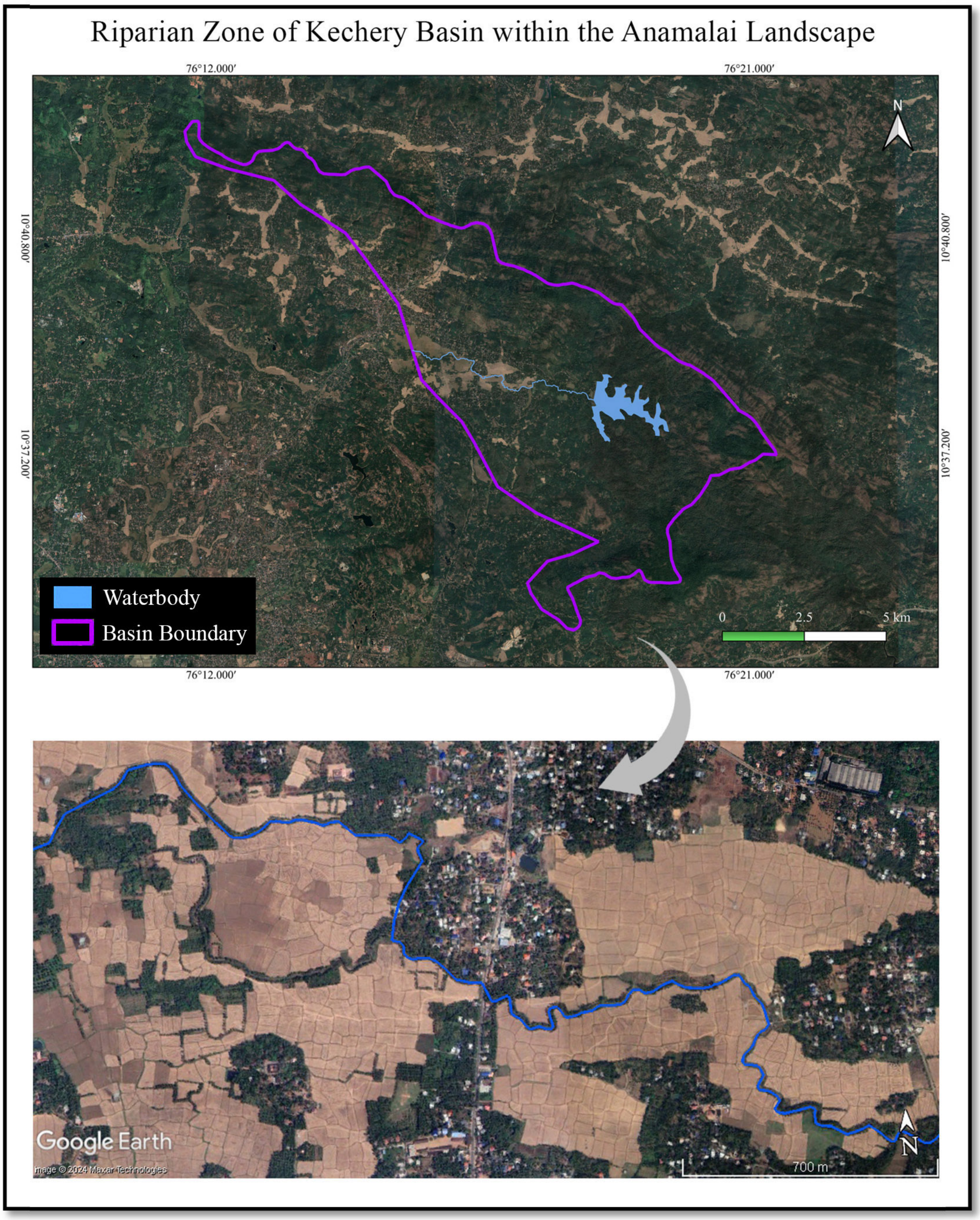


Fig. 4.39. Google Earth imagery of the Kechery basin

The riparian zone of the Kechery basin, which covers 78.17 km^2 area of the Anamalai landscape (1.86 %) and has a length of 7.94 km, is the basin having the least diverse bioclimates which represents only a single bioclimatic zone, Zone 1- Thrissur Peechi North -West portions of the Anamalai landscape. The study does not find any recognisable natural riparian forest along the river basin. The riparian zone of the Kechery basin inside the landscape is heavily modified and hardly represented by native riparian forests. Consequently, this region was excluded from the analysis of the riparian composition.

4.4. Discussion

Riparian forest mapping is essential in scientific enquiries, riparian forest management and land use planning. GIS-based open-source software like Google Earth Pro and QGIS are helpful for studying land use and land cover. The visual interpretation technique formed the basis for the current study and was validated in the field. Extensive research employs the same visual interpretation techniques to determine vegetation types (Roy et al., 2015; Song et al., 2018; Hamylton et al., 2020; Kattenborn et al., 2021; Kutz et al., 2022).

Table 4.8. River length-wise distribution of riparian forests

Sl No.	River Basin	Name of River	River Length (km)	Dense riparian forests (ha)	Medium-dense riparian forests (ha)	Degraded riparian forests (ha)	Total (ha)	Potential Riparian Zone (ha) 2(30*length of river)
1	Chalakudy Basin	Chalakudy Main River	37.23	61.57	118.50	96.81	276.88	223.38
		Sholayar	22.45	10.39	27.00	45.92	83.31	134.7
		Karappara	16.61	8.76	14.71	20.70	44.17	99.66
		Parambikulam	9.61	4.38	11.76	16.22	32.36	57.66
		Kuriyarkutty	8.32	0.00	0.00	7.87	7.87	49.92
2	Karuvannur Basin	Chimmony	14.72	0.00	0.00	11.17	11.17	88.32
		Mupli	18.96	0.00	0.00	12.24	12.24	113.76
3	Periyar Basin	Idamalayar	24.16	3.39	16.80	39.59	59.79	144.96
		Pooyamkutty	16.37	0.00	10.3	44.18	54.48	98.22
		Pichi Ar	7.32	0.00	0.00	9.13	9.13	43.92
4	Bharathapuzha Basin	Aliyar	9.59	0.00	5.47	7.84	13.31	57.54
5	Pambar Basin	Chinnar (up to Kootar)	7.26	3.30	11.31	11.96	26.57	43.56
		Pambar (up to Amaravathy Reservoir)	19.02	0.00	7.20	58.60	65.80	114.12
6	Kechery Basin	Kechery river	7.94	0	0	0	0	47.64
Total			219.62	91.79	223.05	382.23	697.06	1269.72

Healthy riparian buffer systems can handle multiple stresses (Feld et al., 2018). The minimum width of the riparian buffer zone varies with the order of the river even though considering the minimum 30m buffer suggested by Bachan (2010) on either side of the river, the potential riparian zone covered by each tributary and river basins of the Anamalai landscape and its actual existing riparian cover is compared in table 4.8 and 4.9. The minimum riparian zone requirement for the functioning of the river is covered only by the Chalakudy main river of the Anamalai landscape. However, that is not due to the continuity of the canopy but due to the maximum riparian area covered in the Orukombankutty to Vazhachal region of the main river (>30m width in upper regions and <15m width in lower areas). When comparing the longitudinal elevation profiles, Chalakudy main river has its presence and flow in variable elevation gradients, which also contributes to the highest riparian cover of the main river (Fig.4.7.). Moreover, from Athirappilly to Thumburmuzhy, its continuity is highly broken due to external disturbances, where the river covers the most degraded riparian patches of the Chalakudy main river. Other tributaries of the Chalakudy basin and the other four basins are below the minimum buffer width (Table 4.8.).

Table 4.9. Summary of potential riparian zone and riparian forests cover of river basins of the Anamalai landscape

Sl No.	River	Length (km)	Potential Riparian Zone (ha) 2(30*length of river)	Total Riparian Forests (ha)	Percentage of Riparian Forests Present (%)
1	Chalakudy Basin	94.22	565.32	444.59	78.64
2	Periyar Basin	47.85	287.1	123.4	42.98
3	Pambar Basin	26.28	157.68	92.37	58.58
4	Bharathapuzha Basin	9.59	57.54	13.31	23.13
5	Karuvannur Basin	33.68	202.08	23.41	11.58
6	Kechery Basin	7.94	47.64	0	0.00

When comparing the potential riparian zones at the basin level, the Chalakudy basin has the highest riparian cover. 78.64% of the potential riparian zone of the Chalakudy basin has riparian forests. However, the remaining five river basins of the landscape have riparian forest cover below the potential riparian area. Karuvannur and Kechery are the basins with the lowest potential riparian cover (Table 4.9.). According to Broadmeadow and Nisbet (2004), it is difficult to determine a precise minimum buffer width that will guarantee the protection of all freshwater ecosystems from every potential threat, even though widths between 5 to 30 m provide 50-75% and even more effective at maintaining the various functions connected with undisturbed forest streams. Similarly, Dala-Corte et al. (2020) confirm that to maintain Brazil's freshwater biodiversity, 50-m wide riparian buffers on either side of streams would be more successful.

The study got a maximum riparian width of greater than 50m from low elevation dense riparian stretch of Chalakudy River, which is reported as the highest in the diversity of plants, birds, butterflies, and odonates from previous studies (Bachan, 2003; Pooja et al., 2020; Bachan et al., 2022). Although the Anamalai landscapes sixth or higher order rivers to fulfil their ecological functions, a minimum 50 m width is ideal. However, rivers of lower order can function effectively with a minimum width of 30 m with a continuous canopy. Riparian forests with a continuous unbroken canopy are more significant than the width of the riparian buffer. This also agrees with the observations of Bachan (2010) that the wet tropical regions like the Anamalai landscape, with a minimum of 30 m width and a continuous unbroken canopy of riparian forest, help to carry out the functions of the riparian ecosystem. Even though the order of each river plays a crucial role in deciding the potential riparian buffer width. Hence, that needs to be investigated further in future studies, especially for the Western Ghats rivers, which need to be delineated, restored and preserved.

Several studies used GIS to map riparian zones: Through visual interpretation of high-spatial-resolution Google Earth images, Song et al. (2018) mapped the riparian vegetation of the Lake Tana basin, the critical watershed of the Nile Basin, Ethiopia. Also, the middle Rio Grande River's riparian vegetation was mapped by Akasheh et al. (2008) using high-resolution multi-spectral aerial remote sensing techniques. The findings are comparable to the study by the Upper Thames River Conservation Authority (2008), which identified that the 36 km sixth-order stream of Thames Centre has 166 ha of riparian vegetation. The research by Doody et al. (2014) derived 59 ha of riparian vegetation from WV2 image classification within the 29 km river length, which comprises native trees, shrubs, and willows. According to our findings, the 37.23 km Chalakudy main river alone has 276.88 ha of riparian vegetation. This cannot be compared to a different climatic regime of the world, even though it emphasises the significance of riparian vegetation of the Anamalai landscape. Most of the works concentrate on flora and ecological aspects of riparian zones, except the works of Bachan (2003) map and quantified the extent of riparian vegetation based on field surveys and GIS. Studies not reported from the Indian region. The riparian forest cover along the Chalakudy River was estimated by Bachan (2010) to be 480 ha within 145 km^2 of river length, which is only 0.32 % of the total area of the river Basin. Currently, 444.59 ha of riparian forest has been mapped from the Chalakudy River basin within 94.22 km of the river within the Anamalai landscape. The difference could be due to the loss of riparian forest of the Chalakudy main river during the unusual reservoir operation of the Poringalkuthu dam during the flood of 2018, as reported by Bachan et al. (2019).

Compared to the riparian forests of the major tributaries of the western wet slopes of the Anamalai landscape, the Aliyar and the Chinnar tributary has a less riparian area, except for the portions of the Kechery, Chimmony, Mupli, Pichi Ar and Kuriyarkutty tributaries in the western slopes having highly degraded and modified riparian zones due to plantations and human land uses with the potential bioclimates for evergreen and moist deciduous riparian forests. Kuriyarkutty is the tributary with the lowest existing riparian area when comparing all the tributaries of the landscape due to the highest plantation areas and degraded riparian zone. Aliyar also has a riparian zone that has been degraded and modified. In the case of the Chinnar River that has only 18 km in length and passes through dry rain shadow areas of the Anamalai hills. When it reaches the Amaravati reservoir, the degradation of riparian forest types increases due to more external disturbances. In this available smaller area, the river covers 26.57 ha of riparian forests, which is 61% of its potential riparian zone, signifying its importance in providing a wet habitat for flora and fauna compared to the surrounding rain shadow, dry deciduous and thorn forests of Chinnar Wild Life Sanctuary.

Table 4.10. Bioclimatic zones and riparian area of the Anamalai landscape (ha)

Sl. No.	Bioclimatic Zone	Dense Riparian Forests (ha)	Medium Dense Riparian Forests (ha)	Degraded Riparian Forests (ha)	Total (ha)
1	Zone 1- Thrissur Peechi North-West portions of the Anamalai landscape	0	0	23.41	23.41
2	Zone 2-Kuttampuzha and Pooyamkutty Valley	2	14.02	40	56.02
3	Zone 3- Low elevation western slope of the Anamalai landscape	60	143.5	150.78	354.28
4	Zone 4- Sholayar Valley and Northern Valparai Plateau	7	23	39	69
5	Zone 5- Southern Valparai Areas	0	2	16	18
6	Zone 6- Nelliyampathy areas of the Anamalai landscape	0	0	0	0
7	Zone 7- Munnar and Eravikulam region	0	0	0	0
8	Zone 8- Eastern edges of Munnar, Valparai plateau adjoining Munnar	0	5	5	10
9	Zone 9-Parambikulam valley	19.4	16.03	33.23	68.66
10	Zone 10- Top slip region	0	0	1	1
11	Zone 11- Eastern slope of the Anamalai landscape adjoining Sarkarpatti, Aliyar, Chinnar and Maraur Valley	0	1	3	4
12	Zone 12- Maraur and Aliyar valleys	0	0.4	10	10.4
13	Zone 13-Chinnar valley	3.39	18.1	60.81	82.3
Total		91.78	223.04	382.23	697.06

The Bharathapuzha basin displays the most diverse range of bioclimatic zones (11 zones). However, it only includes a single tributary inside the landscape (Aliyar River). This is followed by the Chalakudy basin (9 zones), with the highest number of tributaries (4) within the landscape boundary. The least variations in bioclimatic zonation were identified from the Karuvannur (2 zones) and Kechery basin (1 zone) within the Anamalai landscape. The riparian forests of the bioclimatic Zone 3- Low elevation western slope of the Anamalai landscape covers the highest riparian forest area (354.28 ha), representing the low-elevation areas of the Chalakudy main river from Orukombankutty to Tumburmuzhy, Karappara river, and portions of Idamalayar and Pooyamkutty rivers. This is followed by the riparian forests of the bioclimatic Zone 1- Thrissur Peechi North-West portions of the Anamalai landscape (82.30 ha) covering the entire Chimmony and Mupli riparian zone. The Zone 6 - Nelliyampathy areas of the Anamalai landscape and Zone 7 - Munnar and Eravikulam region do not represent any riparian forest due to higher elevations regimes and are represented with streamside riparian forest as described by Bachan (2010).

4.5. Summary

The Riparian forests are critical and unique ecosystems with higher species diversity and ecological significance but are also threatened. The vegetation mapping of the riparian vegetation of the Anamalai landscape showed that there are 697.06 ha. of riparian forests within the 4200 km^2 area of the Anamalai landscape. Dense riparian vegetation covers 13.17 % (91.79 ha), medium dense riparian vegetation covers 32 % (223.05 ha), and the degraded riparian vegetation is 54.83 % (382.23 ha). Within the landscape, the Chalakudy basin has the highest riparian vegetation (444.59 ha). Followed by the Periyar basin (123.39 ha), Pambar (92.37 ha), Karuvannur (23.41 ha) and the least riparian forest area is covered by the Bharathapuzha basin (13.31 ha). The Chalakudy basin has riparian forests covering 78.64 % of the potential riparian zone, while the Karuvannr (11.58%) and the Kechery basins show the least cover. As a result of heavily modified riparian zones for human land uses, the Kechery basin has no significant native riparian vegetation within the landscape boundary. The vegetation maps can be used as base data to compare the loss of riparian forests over time, which is crucial for natural resource management and land use planning. Consequently, the study aids in prioritising riparian zones for conservation and bioclimate-based restoration of riparian forests of the Anamalai landscape to enhance the regeneration of riparian forests.

Chapter - 5

Chapter - 5

RIPARIAN COMMUNITY COMPOSITION AND CLASSIFICATION IN RELATION TO BIOCLIMATE IN THE ANAMALAI LANDSCAPE

5.1. Introduction

The balance of the carbon budget and the climate stability is aided by vegetation (Wu et al., 2020). Tropical forest ecosystems are the most crucial habitat for preserving biodiversity and regulating the Earth's short-term climate and are recognised as significant centres of carbon storage (Sullivan et al., 2017; Baldo et al., 2023). Tropical rainforests are home to half of all Earth's species, which cover less than 7% of the Earth's geographical area and also include almost two-thirds of the estimated 350,000–500,000 species of flowering plants on Earth, corresponding to around 40% of terrestrial net primary production and half of the planet's vegetative carbon reserves in storage, which are lower than 10% of the soil's carbon stocks (Gallery, 2014). Most terrestrial and freshwater groups are more diversified in tropical areas than temperate ones, lower altitudes than higher ones, and in forests rather than deserts (Gaston, 2000).

Plant demography studies try to comprehend population dynamics or fluctuations in plant populations over time and space. They also focus on the interplay of abiotic and biotic elements contributing to population fluctuations (Pico et al., 2008). Plant communities exist as species groups in a particular geographic area and are distinguished by a comparatively uniform patch from nearby vegetation types (Pott, 2011). Plant community ecology studies the behaviour and distribution of multi-species associations of plants through time (Austin, 1999). Phytosociology involves the study of plant community composition, evolution, coexistence, and relationships between constituent species with a focus on their classification based on the floristic composition of sampling plots (Ewald, 2003; Dengler et al., 2008; Dengler, 2017). It has heuristic value for demographic evaluations (Wilmanns, 1985), and it provides information on the dynamics of vegetation cover, climate change, and other variables that can influence plant development, dynamics of invasive and endangered species, and evaluations of the impacts of human activities on vegetation. Furthermore, it is a tool with enormous potential that has not yet been realised (Konatowska & Rutkowski, 2019).

The study of vegetation at all levels of complexity, including populations, plant communities, and biomes, is the focus of vegetation science. It tries to explain vegetation patterns and the mechanisms that regulate vegetation formation and dynamics at all temporal and geographical scales (Pott, 2011). Migration and environmental selection result in the development of vegetation. Climax vegetation is a stage where effective changes have stopped and restart at any later period, which might lead to the beginning of a new succession (Gleason, 1926). A climax, or sequence of climaxes, represents the result of a progressive succession. Under a particular climate, all successions converge on a single climatic climax; therefore, interference related pre-climax vegetation must be considered as secondary vegetation (Clements, 1936; Bachan, 2010). Since the early 19th century, vegetation scientists have investigated fragments of vegetation that they regarded as samples of a plant community (van der Maarel, 2005). Climate's significance in explaining vegetation distribution was recognised early by De Candolle (1855, as cited in Joseph, 2009). Climate and physical environmental parameters have been widely used to explain key vegetation patterns worldwide (Holdridge, 1967; Mather & Yoshioka, 1968; Zhang et al., 2004). According to Gleason (1917), plant associations, or regions of homogenous vegetation, evolve as a result of similar environmental selection and available immigration sources, and these may undergo substantial changes as a result of significant changes in the environment or the adjacent population of the area. The process is termed succession if these modifications result in a new association.

5.1.a. Riparian plant communities

The presence of vegetation along a stream may influence a wide range of biotic and abiotic processes, having complicated implications on the structure of the stream and the dynamics of the water flow. The type of vegetation, its mechanical properties, density, and spatial distribution affect the intensity of these impacts (Fashae & Obateru, 2023). Humans frequently shape this vegetation with induced perturbations (Holmes et al., 2005). The stability of riverbanks, nutrient cycling, flood mitigation, control of stream temperatures and flows, groundwater recharge, and water filtration are influenced by riparian plant communities (Kauffman et al., 1997; Tickner et al., 2001). In both urban and rural locations, they serve as a refuge for animals, serve as corridors for the migration of various species and plant propagules, and improve the aesthetic value of landscapes (Naiman & Decamps, 1997; Hennings & Edge, 2003; Lehmkuhl et al., 2007; Klapproth & Johnson, 2009). Clearing riparian forests results in fragmentation; even 1 ha of forest clearance can completely isolate all upland forests, which results in topsoil erosion and damage to existing vegetation due to the exposure of full-forced water in the rainy season (Veneklaas et al., 2005). Riparian plant communities are influenced by regular flooding and interactions with nearby ecosystems through material and energy exchange (Majumdar et al., 2020). Increased frequency of flood pulses will benefit local plant communities (Tiegs et al., 2005). The major factors impacting soil nutrients were structural features of riparian plant communities. Moreover, riparian forest type substantially impacts the soil properties in riparian zones, and each plant species in riparian habitats contributes to the organic matter inputs (Franca et al., 2009; Zhao et al., 2020).

5.1.b. Riparian vegetation composition and classification

Understanding an area's ecological dynamics requires an understanding of the vegetation composition and structure. To evaluate forest richness and recognise the entire biological makeup of a forests floral composition, species diversity, and community types are essential factors (Anamo et al., 2022). It is essential to comprehend the structure and composition of vegetation to evaluate the diversity and health of an ecosystem, as well as for the riparian forest ecosystems. It also enables us to recognise changes in stand structure and composition over time. It can acquire vital data to support efficient riparian zone management, planning, monitoring, making policies and for the sustainable use of the riparian forests. This knowledge helps to anticipate changes and make wise choices about ecological management and conservation measures. Vegetation classifications create a systematic framework for classifying plants and help people to comprehend the different kinds of vegetation available in a given area. Effective natural resource monitoring, management, and conservation rely on this classification. A detailed comprehension of the tree species composition and forest stand structure is also required for creating successful conservation programmes (Almulqu et al., 2018).

Classification looks into and clarifies the ecological relationships between different plant communities that make up a vegetative cover. According to Gleason (1926), communities differ significantly from place to place, so categorising them was inappropriate. However, in later years, environmental classification systems such as Koppen (1936), Holdridge (1947), Thornthwaite (1948) and Prentice (1990); floristic classifications by Clements (1916, 1928) and Tansley and Chipp (1926); physiognomic classification by Kuchler (1949), Webb (1959), Gaussen et al. (1961), Fosberg (1967), Ellenberg and Muller-Dombois (1967) and Beard (1978) have emerged.

The riparian vegetation type and structure strongly influence the diversity and health of the riparian ecosystem. Recognising and classifying the various vegetation types present in riparian zones is necessary for better understanding the ecological role of riparian vegetation and managing river ecosystems (Amaludin et al., 2022). Significant research on the composition and classification of riparian vegetation has previously been conducted only from a few parts of the world, including riparian habitat in the South-west (Pase & Layser, 1977); Animas River, Southwestern Colorado (Walford et al., 1995); Montana's riparian and wetland sites (Hansen, 1995); Colorado river (Baker, 1989; Kittel et al., 1999); Eastern Idaho, Western Wyoming (Youngblood, 1985); Utah and Southeastern Idaho (Padgett, 1989) and for the Damyang riparian wetland (Ahn et al., 2016).

In recent years, many rivers have been subject to in-depth investigations on the floristic diversity of riparian vegetation across India. Some significant studies have been conducted for the Tambiraparani River (Johnsingh & Joshua, 1989); Chalakudy River (Bachan, 2003, 2010); Valapattanam River (Sreedharan, 2005); Yamuna River (Chauhan & Gopal, 2005); Cauvery River (Sunil et al., 2012); Alakyam stream (Manoj et al., 2012); Pamba River (Joby, 2012); Sokanasini River (Sherina et al., 2018); Dikhu River (Devlin & Singh, 2018); Ganga River (Shruti et al., 2019); Alaknanda and Bhagirathi Basin (Dharmveer, 2019); Amirthi River (Sakthivel et al., 2019); Chaliyar River (Mohanan et al., 2020; Mohanan, 2023); Thuthapuzha subbasin (Jisha, 2020); Tungabhadra River (Siddeshwari & Kotresha, 2023). However, none of them, excluding Bachan (2010) for the Chalakudy basin of the Anamalai landscape, attempted a bioclimate based approach to study and categorise the riparian forests.

Champion and Seth (1968) revised the classic study on India's vegetation by Champion (1936) based on a few selected stands. The study's flaw is the confusion between physical and anthropogenic factors. The degradation phases of the same original climax were considered as separate climax states and criticised by Puri et al. (1983) and Meher- Homji (2001). Another comprehensive analysis of vegetation classification was done by Meher-Homji (2001) because it includes all available vegetation types and acts as the superior replacement for the Champion and Seth classification (1968). Chandrasekharan (1962) gives a vegetation classification for Kerala by updating Champion and Seth (1936). These are the important studies on vegetation classification that emerged from the Indian region. Even though the earliest record of riparian vegetation in India comes from Champion and Seth (1968), where the study defined Riparian Fringing Forest (RS1/4E) and Dry Tropical Riverine Forests (IS1) subgroups under the Moist tropical and Dry tropical vegetation types, respectively, however, this vegetation only represents riparian forests along the rivers in the drier regions of the Indian peninsula. Before Bachan (2003), no significant research was conducted on riparian forests in the wet zones of the Western Ghats. The remaining rivers of the Anamalai landscape, except for the Chalakudy (Bachan, 2010) and the Karuvannur (Nizammudeen et al., 2015, 2016, 2017) basins are not subject to phytosociological examinations. For the first time, the classification of the riparian forest types was given by Bachan (2010, 2023) and Bachan et al. (2022), with distinct subtypes of Dry, Moist, Evergreen, and Wet evergreen forest types in addition to those described by Champion and Seth (1968) within the Indian Sub-continent. More studies are required to understand riparian forest compositions and types in relation to heterogenic bioclimatic attributes of the region. An in-depth understanding of the riparian forest types, their composition, and classification for each river basin of the Anamalai landscape unit can ensure a basin-level approach to the conservation and management of the threatened riparian ecosystem.

The present chapter intends to identify riparian vegetation compositions to describe the species associations within the Anamalai landscape towards its classification. Thus, the study provides a detailed account of riparian community compositions within the Anamalai landscape and classified according to the existing bioclimatic vegetation classifications (Meher- Homji, 2001; Bachan, 2010; Bachan et al., 2022; Bachan, 2023).

5.2. Methodology

5.2.a. Sampling design, identification of sampling sites and collection of data

The prepared riparian maps were used here to decide the sampling locations, and non-riparian areas were eliminated. 150 samples were taken based on a stratified random method (Haullier & Carpentier, 1998) using the presence and extent of the available riparian forest. A reconnaissance survey (100 m transect) was conducted in the selected riparian sites. Thus, the repeated sampling of similar bioclimatic regions was avoided, and the sampling sites were fixed. The data collected for riparian areas of Chalakudy River Basin (Bachan, 2010) was used for analysis with proper ground truthing and updation to save sampling effort and time. The remaining sampling sites were selected, plots were laid out and enumerated between 2018 to 2022 for riparian plant communities.

Table. 5.1. Distribution of sampling plots

<table>
<tr><th>Biome</th><th colspan="2">Vegetation Type</th><th>No. of Plots taken</th></tr>
<tr><td rowspan="5">T1 – Tropical subtropical Forest Biome</td><td rowspan="3">T1.1. Rp. Tropical Moist Riparian Forest</td><td>T1.1i.Rp.Tropical Moist Deciduous Riparian forests (TMDRp)</td><td>55</td></tr>
<tr><td>T1.1.ii.Rp.Tropical Wet-evergreen Riparian Forests (TWEvRp)</td><td>25</td></tr>
<tr><td>T1.1.iii. Rp. Tropical low elevation Evergreen Riparian Forests (TLeERp)</td><td>34</td></tr>
<tr><td colspan="2">T1.2. Rp. Tropical Dry riparian forest (TDRp)</td><td>6</td></tr>
<tr><td colspan="2">T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp)</td><td>15</td></tr>
<tr><td colspan="3">Total plots in the final analysis</td><td>135</td></tr>
</table>

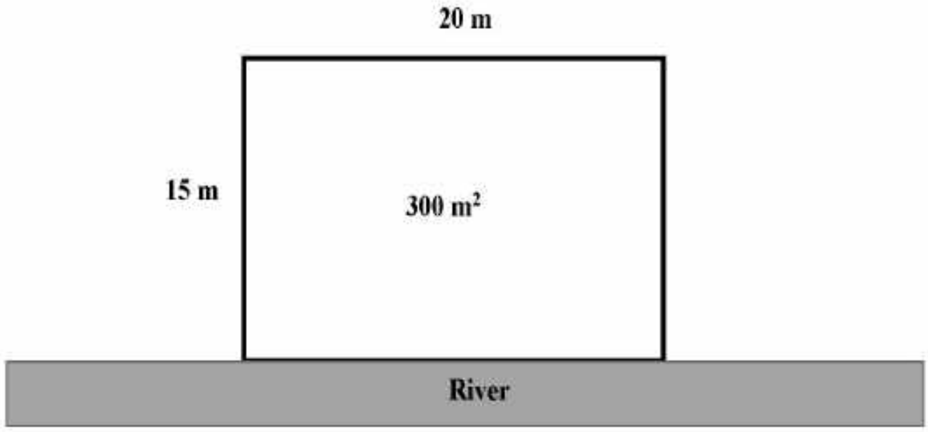


Fig. 5.1. Quadrat used for the phytosociological analysis of riparian forests

At each sampling site, at least three sampling plots of 15m x 20 m (300 m^2) were laid out according to Haullier and Carpentier (1998) and Bachan (2010). The sample plots were constructed longitudinally from the stream boundaries to the edge of the water or active channel. The number of individuals and their Girth at Breast Height (GBH) were recorded. All plants with a GBH greater than 30 cm were recognised and recorded up to the species level. All species with 50% of the base outside the quadrat boundary were excluded from sampling. Measurements for buttressed trees were made from above the buttress. The total culms were counted and multiplied by the average GBH for bamboo and reeds. For plants with multiple stems, the GBH of each stem is summed (Bachan, 2010; National Working Plan Code, 2014). Each species was identified using Flora of Presidency of Madras by Gamble and Fischer (1915-1936) and riparian flora of the Chalakudy basin by Bachan (2010) and the Pamba basin by Joby (2012). The online databases of the International Plant Names Index (https://www.ipni.org/), Plants of the World Online (https://powo.science.kew.org/), and E-Flora of Kerala (https://www.eflorakerala.com/) also used for the identification and nomenclature validation of each species.

5.2.b. Riparian community compositions and classification of riparian forest types and subtypes

The compositions were clustered based on species similarity index (Bachan, 2010; Bachan et al., 2019). The Bray-Curtis similarity index utilising the UPGMA algorithm (Unweighted Pair Group Method with Arithmetic Mean) clustering analysis was performed on all sample plots to construct a dendrogram using PAST

4.03 statistical software (Hammer et al., 2001). The clustering of the sampling plots based on the species similarity brought sampling plots with homogenous species composition together, which helped to understand heterogenic species clusters. This was successfully used to understand the heterogeneity in phytosociological sampling units and, hence, on plant community compositions (Bachan, 2010; Bachan & Pradeep, 2010; Bachan et al., 2014; Bachan et al., 2019). Plot data for the identified cluster groups were compiled and analysed to determine the density, frequency and basal area. The important value index (IVI) is derived from the sum of the relative values of frequency, density, and basal area (Daubenmire, 1959; Misra, 1968; Weaver & Clements, 1983; Romesburg, 1984; Jongman et al., 1995).

Table. 5.2. The phytosociological and statistical formulations used in the study

1. Density (D) = $\frac{\text{Total number of individuals of the species}}{\text{Total number of quadrats studied}}$
2. Frequency (F) = $\frac{\text{Total number of quadrats in which species occurred}}{\text{Total number of quadrats studied}}$
3. Basal area (BA) = $\frac{(GBH)^2}{4\pi}$
4. Relative Frequency (RF) = $\frac{\text{Frequency of the species}}{\text{Total frequency of all the species}} \times 100$
5. Relative Density (RD) = $\frac{\text{Density of the species}}{\text{Total density of all the species}} \times 100$
6. Relative Basal area (RBA) = $\frac{\text{Basal area of the species}}{\text{Total basal area of all species}} \times 100$
7. Importance Value Index (IVI) = RF + RD + RBA
8. Dominance index (D) = $\Sigma\,(ni/N)^2$
9. Simpson's diversity index = 1 − D
10. Shannon diversity index (H) = - Σ [(ni / N) log2 (ni / N)]

    Where ni = Number of individual species

    N = total number of individuals of all the species in the community
11. Buzas and Gibson's evenness = e^H / s

    Where e is the base of the natural logarithm,

    H is the Shannon diversity index,

    S is the number of species

The IVI was used to identify species that had overall dominance in each cluster, and such dominating species were taken as indicator species to represent each riparian plant community composition. Different strata were represented by listing co-dominant species to designate community types, and the most dominant species will be listed at the beginning (Huerta et al., 1994). Based on floristic and community associations, all these enumerated riparian forest compositions were grouped into representative bioclimates (Meher- Homji, 2001) and classified according to the existing riparian forest classifications (Bachan, 2010; Bachan et al., 2022; Bachan, 2023). Shanon diversity index (H), Simpson's diversity index (1-D), Dominance index (D), and Evenness (Simpson, 1949; Shannon & Weiner, 1963; Buzas & Gibson, 1969; Pielou, 1969, 1975, 1984; Jeffers, 1978; Magurran, 1988) were determined by using PAST 4.03 statistical software. These data were used to compare each riparian forest type obtained through the study.

5.3. Results

Analysing the composition of riparian vegetation in the Anamalai landscape helps to open up the richness of this distinct and dynamic ecosystem. Each basin of the Anamalai landscape has a different bioclimate in its different elevation gradients. Reservoir operations, past forest management practices and physiography have affected various riparian vegetation types in the Anamalai landscape and have resulted in the degradation of riparian vegetation.

5.3.a. Riparian community compositions of the Anamalai landscape

The hierarchical cluster analysis based on the Bray-Curtis similarity index utilising the UPGMA algorithm of the Anamalai landscape revealed 11 major cluster groups, with 32 sub-clusters and four odd cluster Groups (Fig. 5.2.) having different similarity coefficients. The riparian forest enumeration data served as the basis for the analysis. There were 215 tree species represented in the data collected from 150 plots. The cluster group, which did not fit into any significant clusters, were identified as odd and treated independently in the plant community analysis. The community compositions for the identified riparian clusters are given in Table 5.3.

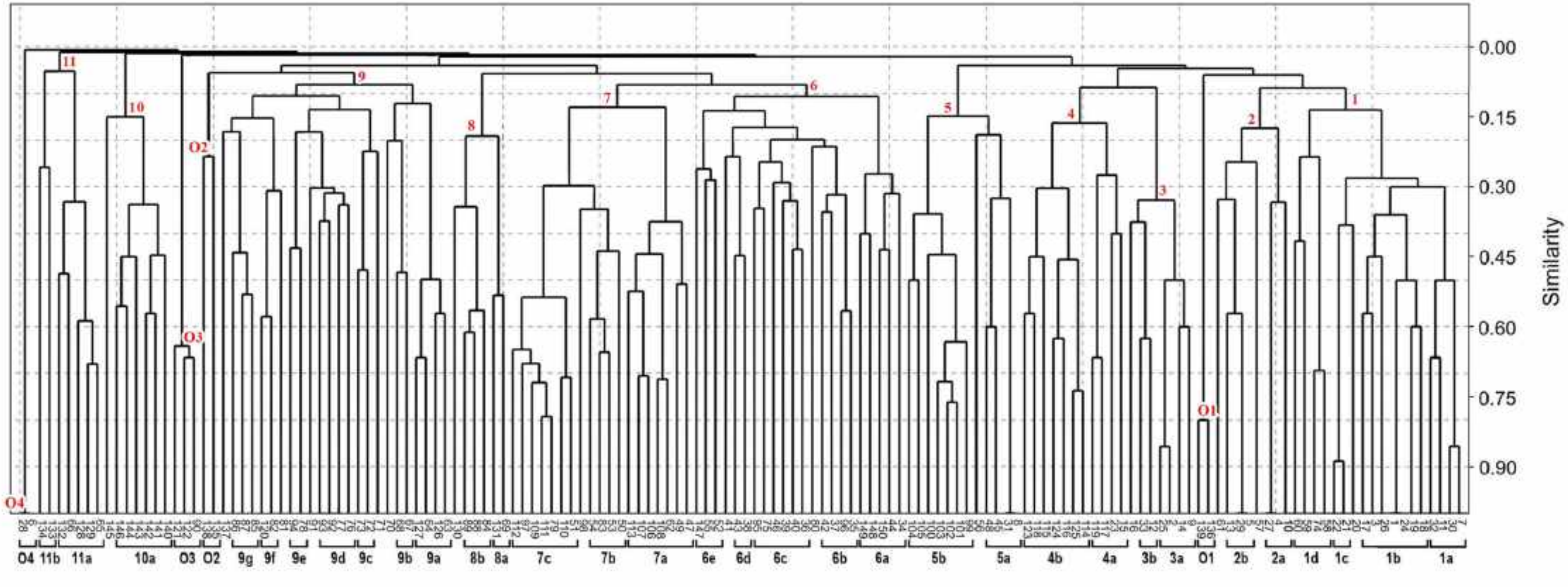


Fig.5.2. Bray-Curtis similarity dendrogram of the riparian plots within the Anamalai landscape

The separately pooled quadrat data for the identified 36 sub-clusters were examined for the Density (D), Frequency (F), Basal Area (BA), and Importance Value Index (IVI). The IVI analysis identified dominant species associations for each riparian forest type and subtype, which gave a concise summary of the community composition for each of the 36 riparian forest subtypes identified. Detailed data on the IVI Analysis and the correlation between the identified clusters are provided in Appendix IV and V, respectively.

Table. 5.3. Community composition of the identified clusters

Major Cluster	Sub Cluster	Similarity coefficient (%)	Species composition
Cluster 1	Sub Cluster 1a	50	*Caryota urens /Lagerstroemia speciosa /Ficus hispida /Hydnocarpus pentandrus /Dalbergia latifolia /Homonoia riparia*
	Sub Cluster 1b	35	*Lagerstroemia speciosa /Gmelina arborea / Mitragyna parvifolia /Macaranga peltata / Alstonia scholaris /Homonoia riparia*
	Sub Cluster 1c	90	*Lagerstroemia speciosa /Pterospermum reticulatum /Homonoia riparia / Actinodaphne wightiana /Spondias pinnata*
	Sub Cluster 1d	25	*Lagerstroemia speciosa /Mallotus philippensis / Machilus macranthus/ Holigarna arnottiana /Tetrameles nudiflora / Ochlandra scriptoria*
Cluster 2	Sub Cluster 2a	35	*Mitragyna parvifolia /Hydnocarpus pentandrus/ Homonoia riparia*
	Sub Cluster 2b	55	*Hydnocarpus pentandrus /Gmelina arborea /Holigarna arnottiana /Myristica beddomei*
Cluster 3	Sub Cluster 3a	50	*Caryota urens /Holigarna arnottiana /Ficus hispida /Macaranga peltata /Grewia tiliifolia /Homonoia riparia*
	Sub Cluster 3b	65	*Ficus amplissima /Caryota urens /Holigarna arnottiana /Artocarpus hirsutus /Syzygium cumini /Artocarpus heterophyllus*
Cluster 4	Sub Cluster 4a	25	*Ficus hispida /Maesopsis eminii /Elaeocarpus tuberculatus /Homonoia riparia /Albizia odoratissima*

Major Cluster	Sub Cluster	Similarity coefficient (%)	Species composition
	Sub Cluster 4b	30	*Debregeasia longifolia /Datura stramonium / Ficus hispida / Tetrapilus dioicus / Albizia odoratissima /Homonoia riparia*
Cluster 5	Sub Cluster 5a	35	*Macaranga peltata /Terminalia paniculata /Wrightia tinctoria /Trema orientalis /Cassia fistula L./Lannea coromandelica /Ziziphus rugosa /Ochlandra scriptoria*
	Sub Cluster 5b	35	*Mallotus nudiflorus / Macaranga peltata / Gmelina arborea /Pongamia pinnata / Briedelia retusa*
Cluster 6	Sub Cluster 6a	25	*Ochlandra scriptoria /Ochlandra travancorica /Tetrameles nudiflora / Macaranga peltata /Homonoia riparia / Cinnamomum riparium*
	Sub Cluster 6b	35	*Humboldtia vahliana /Schleichera oleosa /Barringtonia acutangula /Holigarna arnottiana /Vitex altissima /Leea indica /Mallotus atrovirens /Lagerstroemia microcarpa /Aporosa cardiosperma/ Ochlandra scriptoria / Mallotus nudiflorus*
	Sub Cluster 6c	25	*Barringtonia acutangula /Humboldtia vahliana /Syzygium occidentale /Vateria indica /Mallotus atrovirens /Homonoia riparia /Ochlandra scriptoria*
	Sub Cluster 6d	45	*Vateria indica /Holigarna arnottiana /Ochlandra scriptoria /Myristica beddomei / Gmelina arborea /Madhuca neriifolia /Mycetia acuminata /Garcinia morella /Xanthophyllum arnottianum/ Syzygium occidentale/ Barringtonia acutangula*
	Sub Cluster 6e	25	*Bambusa bambos /Barringtonia acutangula / Ochreinauclea missionis /Madhuca neriifolia /Ochlandra scriptoria/Cinnamomum riparium*
Cluster 7	Sub Cluster 7a	40	*Bambusa bambos /Macaranga peltata / Syzygium occidentale /Madhuca neriifolia / Terminalia paniculata /Tetrameles nudiflora / Pandanus furcatus /Ochlandra scriptoria*

Major Cluster	Sub Cluster	Similarity coefficient (%)	Species composition
	Sub Cluster 7b	45	*Ochlandra scriptoria /Madhuca neriifolia /Vateria indica /Barringtonia acutangula / Hopea indica /Lagerstroemia microcarpa /Mallotus aureopunctatus /Ochlandra travancorica*
	Sub Cluster 7c	55	*Ochlandra scriptoria /Bambusa bambos / Humboldtia vahliana /Salix tetrasperma / Tetrapilus dioicus /Vitex leucoxylon/ Mallotus udiflorus /Barringtonia acutangula*
Cluster 8	Sub Cluster 8a	55	*Salix tetrasperma /Ochlandra travancorica / Vateria indica / Meliosma simplicifolia / Monoon fragrans*
	Sub Cluster 8b	55	*Ochlandra travancorica /Mallotus resinosus/ Cinnamomum malabatrum /Lagerstroemia microcarpa /Vitex altissima /Vateria indica /Turpinia malabarica /Knema attenuata /Litsea floribunda /Calophyllum calaba*
Cluster 9	Sub Cluster 9a	50	*Madhuca neriifolia /Meliosma simplicifolia / Palaquium ellipticum / Hopea indica / Heritiera papilio*
	Sub Cluster 9b	50	*Syzygium occidentale /Diospyros paniculata /Ochlandra travancorica /Madhuca neriifolia /Aglaia edulis /Lophopetalum wightianum /Cinnamomum malabatrum/Vateria indica /Bhesa indica*
	Sub Cluster 9c	50	*Vateria indica /Terminalia travancorensis / Monoon coffeoides /Polyalthia fragrans /Aglaia lawii /Myristica malabarica /Bombax ceiba /Ochlandra scriptoria*
	Sub Cluster 9d	35	*Chukrasia tabularis /Dysoxylum malabaricum /Vateria indica /Baccaurea courtallensis /Schleichera oleosa /Atuna travancorica /Diospyros crumenata /Knema attenuata /Polyalthia fragrans /Homonoia riparia*
	Sub Cluster 9e	45	*Diospyros crumenata /Otonephelium stipulaceum / Monoon fragrans / Dipterocarpus indicus /Gymnacranthera farquhariana /Homonoia riparia*

Major Cluster	Sub Cluster	Similarity coefficient (%)	Species composition
	Sub Cluster 9f	55	*Cullenia exarillata /Palaquium ellipticum /Pandanus foetidus /Elaeocarpus tuberculatus /Dendrocnide sinuata /Chionanthus mala-elengi /Vateria indica /Macaranga peltata /Madhuca neriifolia*
	Sub Cluster 9g	45	*Vateria indica /Schleichera oleosa /Poeciloneuron indicum /Cinnamomum cassia /Aporosa acuminata /Callicarpa tomentosa /Cullenia exarillata /Elaeocarpus tuberculatus/Actinodaphne bourdillonii*
Cluster 10		35	*Terminalia arjuna /Pongamia pinnata / Mangifera indica / Hopea indica / Putranjiva roxburghii /Homonoia riparia / Calophyllum calaba*
Cluster 11	Sub Cluster 11a	35	*Maesa indica /Ficus racemosa /Cinnamomum macrocarpum /Syzygium lanceolatum / Meliosma pinnata/Ochlandra scriptoria*
	Sub Cluster 11b	25	*Strychnos nux-vomica /Wrightia tinctoria /Schleichera oleosa /Lawsonia inermis /Ficus racemosa /Homonoia riparia*
Odd Cluster Groups	Cluster O1	80	*Xylia xylocarpa /Wrightia tinctoria/ Filicium decipiens / Bambusa bambos / Lagerstroemia speciosa / Homonoia riparia*
	Cluster O2	25	*Aporosa acuminata /Vitex altissima / Cinnamomum malabatrum /Hydnocarpus alpina/ Madhuca neriifolia*
	Cluster O3	65	*Strobocalyx arborea / Elaeocarpus tuberculatus/ Antidesma montanum /Vepris bilocularis / Artocarpus heterophyllus /Homonoia riparia*
	Cluster O4	90	*Bombax ceiba /Ceiba pentandra/ Homonoia riparia*

5.3.b. Classification of riparian forest types and subtypes within the Anamalai landscape

The pioneering research in riparian ecological studies by Bachan (2003, 2005) recognised the existence of riparian forests as a distinct ecosystem in the moist part of the Western Ghats. It is then followed by classifying riparian forests into 18 distinct subtypes of dry, moist, evergreen, and wet evergreen bioclimates of the Chalakudy river basin of Kerala (Bachan, 2010). In the present study, detailed analyses of other potential bioclimates and their subtypes were revealed within the Anamalai landscape via phyto-sociological analysis, clustering, and classification into distinct types and subtypes based on species composition and presented here as an addition to the existing vegetation classifications of India (Champion & Seth, 1968; Meher- Homji, 2001; Bachan, 2010; Bachan et al., 2022; Bachan, 2023) to fill research gaps in the classification of riparian forest.

Following the methodology of bioclimatic classification of Gadgil and Meher-Homji (1982), Meher-Homji (2001) and Bachan (2010), the 36 identified vegetation subtypes from the Anamalai landscape unit were classified into three major riparian forest types and twenty subtypes including primary and secondary forest types, which corresponds to Dry and Moist major forest types of the broad vegetation classification provided by Champion and Seth (1968) for the Indian subcontinent. All the classified riparian forest types are coded according to Bachan (2010), Bachan et al. (2022), and Bachan (2023), which were based on Champion and Seth (1968) and IUCN global ecosystem typology (Keith et al., 2020). According to Bachan et al. (2022) and Bachan (2023), all the Riparian Forest type in the Peninsular Indian region comes under the T1 – Tropical subtropical forest Biome of Global Ecosystem classification by Keith et al. (2020). This includes the T1.1. Rp. Tropical Moist Riparian Forest, which again divided into three subtypes (1. T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp.), 2. T1.1.ii.Rp. Tropical Wet-Evergreen Riparian Forests (TWEvRp.), 3. T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests -TLeERp.) second type, T1.2. Rp. Tropical Dry Riparian Forest (TDRp.), and the third one, T1.3. Rp. Sub-tropical montane Riparian/ Streamside forests (TStMRp.). Table 5.4. provides a detailed classification of the riparian forests of the Anamalai landscape.

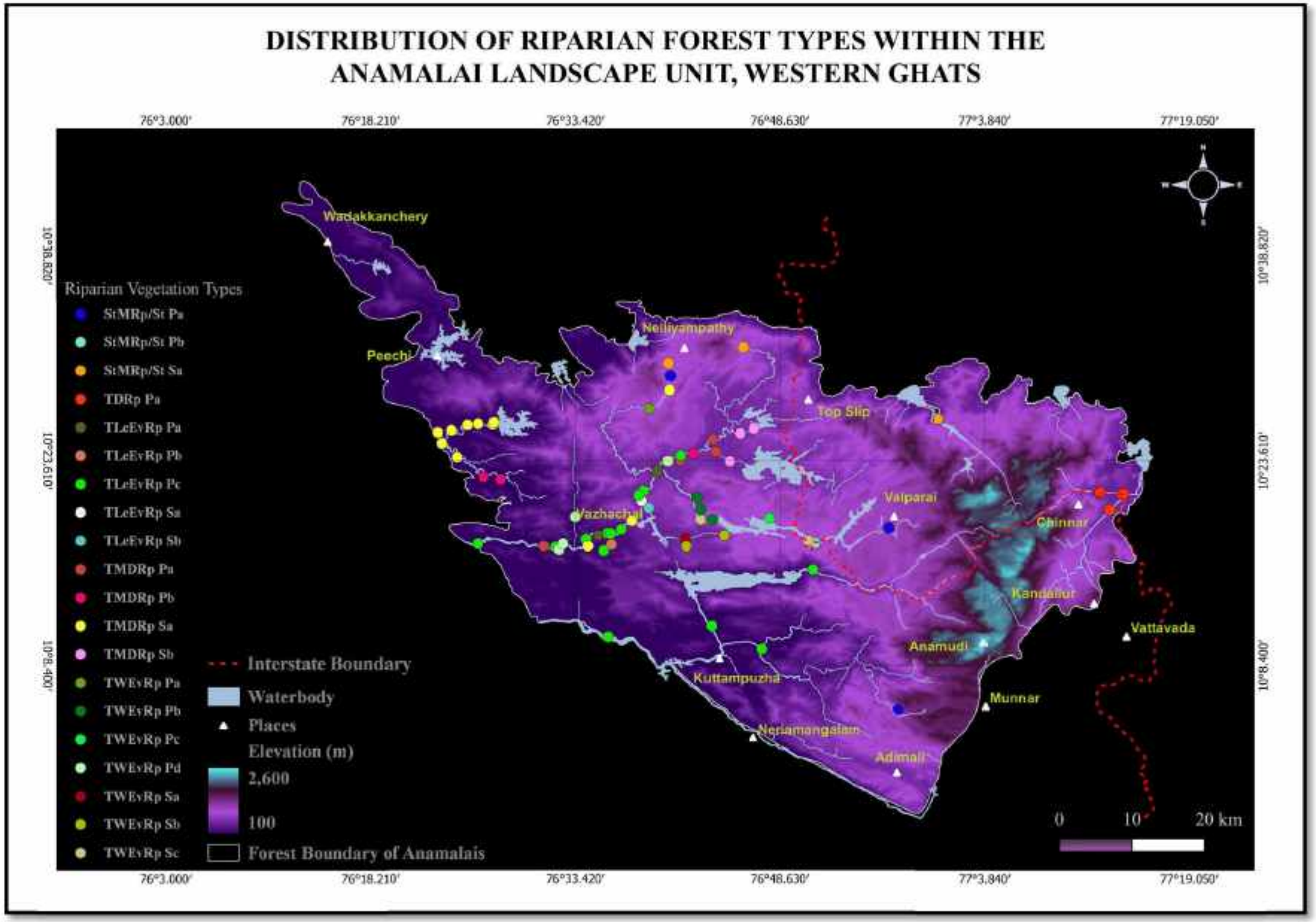


Fig. 5.3. Distribution map of the riparian forest types of the Anamalai landscape

Table. 5.4. Classification of riparian forest types within the Anamalai landscape

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp)	Cluster 7a	TMDRp Pa - Moist Deciduous Riparian Forest	*Bambusa bambos /Macaranga peltata / Syzygium occidentale /Madhuca neriifolia /Terminalia paniculata / Tetrameles nudiflora /Pandanus furcatus / Ochlandra scriptoria*	Athirapilly,Orukombankutty, Parambikulam, Kuriyarkutty
			Cluster 1b	TMDRp Pb - Moist Deciduous Riparian Forest	*Lagerstroemia speciosa /Gmelina arborea /Mitragyna parvifolia /Macaranga peltata /Alstonia scholaris /Homonoia riparia*	Mupli River's upper portions
			Cluster 1c		*Lagerstroemia speciosa /Pterospermum reticulatum /Homonoia riparia / Actinodaphne wightiana /Spondias pinnata*	Mupli River's upper portions

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp)	Cluster 1d	TMDRp Pb - Moist Deciduous Riparian Forest	*Lagerstroemia speciosa /Mallotus philippensis / Machilus macranthus /Holigarna arnottiana / Tetrameles nudiflora /Ochlandra scriptoria*	Kuriyarkutty
			Cluster 1a	TMDRp Sa - Secondary Moist Deciduous Riparian Forest	*Caryota urens /Lagerstroemia speciosa /Ficus hispida /Hydnocarpus pentandrus /Dalbergia latifolia / Homonoia riparia*	Chimmony WLS
			Cluster 5a		*Macaranga peltata /Terminalia paniculata /Wrightia tinctoria /Trema orientalis /Cassia fistula /Lannea coromandelica /Ziziphus rugosa /Ochlandra scriptoria*	Downstream to Chimmony and Poringalkuthu reservoir

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp)	Cluster O 1	TMDRp Sa - Secondary Moist Deciduous Riparian Forest	*Xylia xylocarpa /Wrightia tinctoria/ Filicium decipiens / Bambusa bambos / Lagerstroemia speciosa / Homonoia riparia*	Athirapilly
			Cluster O4		*Bombax ceiba /Ceiba pentandra/ Homonoia riparia*	Lower portions of Mupli and Chimmony River
			Cluster 2a		*Mitragyna parvifolia /Hydnocarpus pentandrus/ Homonoia riparia*	Chimmony river middle strech
			Cluster 2b		*Hydnocarpus pentandrus /Gmelina arborea /Holigarna arnottiana /Myristica beddomei*	Chimmony River's upper stretch

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp)	Cluster 3a	TMDRp Sa - Secondary Moist Deciduous Riparian Forest	*Caryota urens /Holigarna arnottiana /Ficus hispida /Macaranga peltata / Grewia tiliifolia /Homonoia riparia*	Chimmony river
			Cluster 3b		*Ficus amplissima /Caryota urens /Holigarna arnottiana /Artocarpus hirsutus /Syzygium cumini /Artocarpus heterophyllus*	Mupli River Middle stretch
			Cluster 4a		*Ficus hispida /Maesopsis eminii / Elaeocarpus tuberculatus /Homonoia riparia /Albizia odoratissima*	Nelliyampathy
			Cluster 5b	TMDRp Sb - Secondary Dry Deciduous Riparian Forest	*Mallotus nudiflorus /Macaranga peltata / Gmelina arborea /Pongamia pinnata / Briedelia retusa*	Parambikulam, Tunakadav reservoir area

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.ii.Rp.Tropical Wet-evergreen Riparian Forests (TWEvRp)	Cluster 9a	TWEvRp Pa - Wet (Moist) Evergreen Riparian Forest	*Madhuca neriifolia /Meliosma simplicifolia /Palaquium ellipticum / Hopea indica /Heritiera papilio*	Nelliyampathy
			Cluster 9b	TWEvRp Pb - Wet (Moist) Evergreen Riparian Forest	*Syzygium occidentale /Diospyros paniculata /Ochlandra travancorica /Madhuca neriifolia /Aglaia edulis /Lophopetalum wightianum /Cinnamomum malabatrum/Vateria indica /Bhesa indica*	Lower Sholayar Reservoir area
			Cluster 9c		*Vateria indica /Terminalia travancorensis / Monoon coffeoides /Polyalthia fragrans /Aglaia lawii /Myristica malabarica /Bombax ceiba /Ochlandra scriptoria*	Sholayar river Kudal area

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.ii.Rp.Tropical Wet-evergreen Riparian Forests (TWEvRp)	Cluster 9f	TWEvRp Pc - Wet (Moist) Evergreen Riparian Forest	*Cullenia exarillata /Palaquium ellipticum /Pandanus foetidus /Elaeocarpus tuberculatus /Dendrocnide sinuata /Chionanthus mala-elengi /Vateria indica /Macaranga peltata /Madhuca neriifolia*	Sholayar
			Cluster 7c	TWEvRp Pd - Wet (Moist) Evergreen Streamside Riparian Forest	*Ochlandra scriptoria /Bambusa bambos / Humboldtia vahliana /Salix tetrasperma / Tetrapilus dioicus /Vitex leucoxylon/ Mallotus nudiflorus / Barringtonia acutangula*	Athirapilly, Vazhachal, Orukombankutty
			Cluster O 3	TWEvRp Sa - Secondary Semi-Evergreen Streamside Riparian Forest	*Strobocalyx arborea / Elaeocarpus tuberculatus/ Antidesma montanum /Vepris bilocularis / Artocarpus heterophyllus /Homonoia riparia*	Ankayam stream area

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.ii.Rp.Tropical Wet-evergreen Riparian Forests (TWEvRp)	Cluster 8b	TWEvRp Sb - Secondary Semi Evergreen Riparian Forest	*Ochlandra travancorica / Mallotus resinosus /Cinnamomum malabatrum /Lagerstroemia microcarpa /Vitex altissima /Vateria indica /Turpinia malabarica /Knema attenuata /Litsea floribunda /Calophyllum calaba*	Ankayam and Sholayar
			Cluster 8a	TWEvRp Sc - Secondary Semi Evergreen Riparian Forest	*Salix tetrasperma /Ochlandra travancorica /Vateria indica / Meliosma simplicifolia / Monoon fragrans*	Sholayar, Malakkppara
		T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp)	Cluster 9d	TLeEvRp Pa - Low Elevation Evergreen Riparian Forest	*Chukrasia tabularis /Dysoxylum malabaricum /Vateria indica /Baccaurea courtallensis /Schleichera oleosa /Atuna travancorica /Diospyros crumenata /Knema attenuata /Polyalthia fragrans /Homonoia riparia*	Orukombankutty

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp)	Cluster O2	TLeEvRp Pa - Low Elevation Evergreen Riparian Forest	*Aporosa acuminata* /*Vitex altissima* / *Cinnamomum malabatrum* / *Hydnocarpus alpina*/ *Madhuca neriifolia*	Vazhachal
			Cluster 6d	TLeEvRp Pb - Low Elevation Evergreen Riparian Forest	*Vateria indica* /*Holigarna arnottiana* /*Ochlandra scriptoria* /*Myristica beddomei* / *Gmelina arborea* /*Madhuca neriifolia* /*Mycetia acuminata* /*Garcinia morella* /*Xanthophyllum arnottianum* /*Syzygium occidentale*/*Barringtonia acutangula*	Vazhachal
			Cluster 6a	TLeEvRp Pc - Low Elevation Semi-Evergreen Riparian Forest	*Ochlandra scriptoria* /*Ochlandra travancorica* /*Tetrameles nudiflora* / *Macaranga peltata*/*Homonoia riparia* /*Cinnamomum riparium*	Athirapilly, Pooyamkutty, Idamalayar

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp)	Cluster 6b	TLeEvRp Pc - Low Elevation Semi-Evergreen Riparian Forest	*Humboldtia vahliana /Schleichera oleosa /Barringtonia acutangula /Holigarna arnottiana /Vitex altissima /Leea indica /Mallotus atrovirens /Lagerstroemia microcarpa /Aporosa cardiosperma/Ochlandra scriptoria / Mallotus nudiflorus*	Vazhachal, Karanthodu Athirapilly
			Cluster 6c	TLeEvRp Pc - Low Elevation Semi-Evergreen Riparian Forest	*Barringtonia acutangula /Humboldtia vahliana /Syzygium occidentale / Vateria indica /Mallotus atrovirens / Homonoia riparia /Ochlandra scriptoria*	Vazhachal, Karanthodu
			Cluster 6e	TLeEvRp Pc - Low Elevation Semi-Evergreen Riparian Forest	*Bambusa bambos /Barringtonia acutangula /Ochreinauclea missionis / Madhuca neriifolia /Ochlandra scriptoria/Cinnamomum riparium*	Tumburmuzhy, downstream to Boothathankettu reservoir

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp)	Cluster 7b	TLeEvRp Pc - Low Elevation Semi-Evergreen Riparian Forest	*Ochlandra scriptoria /Madhuca neriifolia /Vateria indica /Barringtonia acutangula / Hopea indica /Lagerstroemia microcarpa /Mallotus aureopunctatus / Ochlandra travancorica*	Vazhachal, Orukombankutty area
			Cluster 9e	TLeEvRp Sa - Low Elevation Secondary Semi-Evergreen Riparian Forest	*Diospyros crumenata /Otonephelium stipulaceum / Monoon fragrans / Dipterocarpus indicus / Gymnacranthera farquhariana / Homonoia riparia*	Karanthodu

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)		Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.1. Rp. Tropical Moist Riparian Forest	T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp)	Cluster 11b	TLeEvRp Sb - Low Elevation Secondary Semi-Evergreen Riparian Forest	*Strychnos nux-vomica* /*Wrightia tinctoria* /*Schleichera oleosa* / *Lawsonia inermis* /*Ficus racemosa* / *Homonoia riparia*	Upper areas of the Poringalkuthu reservoir
	T1.2. Rp.Tropical Dry riparian forest (TDRp)		Cluster 10	TDRp Pa - Dry Tropical Riparian Evergreen Foreststst	*Terminalia arjuna* /*Pongamia pinnata* /*Mangifera indica* /*Hopea indica* /*Putranjiva roxburghii* / *Homonoia riparia* /*Calophyllum calaba*	Chinnar, Kootar, Chambakad, Chinnar WLS
	T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp)		Cluster 4b	TStMRp/St Pa - Montane Shola Streamside Riparian Forests	*Debregeasia longifolia* /*Datura stramonium* /*Ficus hispida* / *Tetrapilus dioicus* / *Albizia odoratissima* / *Homonoia riparia*	Valparai, Nelliyampathy, and Munnar

Biome (Keith et al., 2020)	Riparian forest type (Bachan et al., 2022; Bachan, 2023)	Cluster Group	Riparian forest sub-type	Species composition	Locality
T1 – Tropical Subtropical Forest Biome	T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp)	Cluster 9g	TStMRp/St Pb - Montane Evergreen Riparian Forest	*Vateria indica /Schleichera oleosa /Poeciloneuron indicum / Cinnamomum cassia /Aporosa acuminata /Callicarpa tomentosa /Cullenia exarillata /Elaeocarpus tuberculatus/Actinodaphne bourdillonii*	Valparai
		Cluster 11a	TStMRp/St Sa - Montane Shola Streamside degraded Riparian Forest	*Maesa indica /Ficus racemosa / Cinnamomum macrocarpum / Syzygium lanceolatum /Meliosma pinnata/Ochlandra scriptoria*	Nelliyampathy and Aliyar

The primary types of Tropical moist deciduous riparian forests (T1.1i.Rp.) are prevalent in the Parambikulam Valley and the less disturbed upper catchment area of the Karuvannur basin (Mupli River). Additionally, two degradation types of Tropical Moist Deciduous Riparian Forests (TMDRp Sa and TMDRp Sb) are present in disturbed areas of the Chimmony, Mupli rivers, and Parambikulam. It is also found in the evergreen bioclimatic zones (Athirapilly, Nelliyampathy) due to disturbance and edaphic conditions as a secondary form. The Nelliyampathy, Sholayar, Parambikulam, and Orukomban areas of the Chalakudy River are the only places where Tropical Wet-Evergreen Riparian Forests (T1.1.ii.Rp.) can be found with four primary and three secondary types.

Tropical low elevation Evergreen Riparian Forests (T1.1.iii. Rp.) with three primary forms (TLeEvRp Pa., TLeEvRp Pb., and TLeEvRp Pc.) and two degradation types (TLeEvRp Sa. and TLeEvRp Sb.) are found exclusively in the Chalakudy River from Orukombankutty to Thumburmuzhi which confirms the findings of the pioneering studies by Bachan (2003, 2005) and an additional type subgroup 6e of the primary type TLeEvRp Pc identified from very low elevations of Periyar river near Boothathankettu reservoir and also from Thumburmuzhy areas of Chalakudy with the dominance of *Ochreinauclea missionis*. The subgroup 6a. of TLeEvRp Pc was recognised from the lower altitudes of the Idamalayar and Pooyamkutty, tributaries of Periyar and lower altitudes of Chalakudy River.

The tropical dry deciduous riparian forests have been documented from the east-flowing Chinnar and Pambar Rivers of Kerala, classified here as Tropical Dry riparian forests (T1.2. Rp.) dominating with *Terminalia arjuna* and *Pongamia pinnata* were the first mentioned riparian forest type in the dry regions of peninsular India by Champion and Seth (1968) and also recognised by the studies of Sunil et al. (2009, 2011) from Cauvery basin. However, this type is rare in the western slopes of the Anamalai landscape due to the high rainfall regime and is widespread in the eastern slope of the rain shadow region of the Anamalai landscape. Two primary types of Sub-tropical montane riparian/ streamside forest (TStMRp/St Pa and TStMRp/St Pb) from the Valparai, Nelliyampathy and Munnar areas, as well as one degradation type (TStMRp/St Sa.) types also identified from Nelliyampathy and Aliyar areas are included here to represent the Sub-tropical montane riparian/streamside forest (T1.3. Rp.), which is distributed at an elevation above 1500m and acts as an ecotone close to the shola and the wet evergreen forests of higher altitudes (Bachan et al., 2022).

Fig. 5.4. T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp.): A. Parambikulam; B. Topslip; C. Chimmony River; D. & E. Athirappilly; F. Mupli River.

Fig. 5.5. T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp.): A. & B. *Lagerstroemia speciosa* (L.) Pers., A. Fruiting branch, B. Inflorescence; C. *Mallotus nudiflorus* (L.) Kulju & Welzen; D. & E. *Tetrameles nudiflora* R. Br., D. Habit, E. Inflorescence; F. *Homonoia riparia* Lour.; G. *Bambusa bambos* (L.) Voss; H. *Terminalia paniculata* B. Heyne ex Roth.

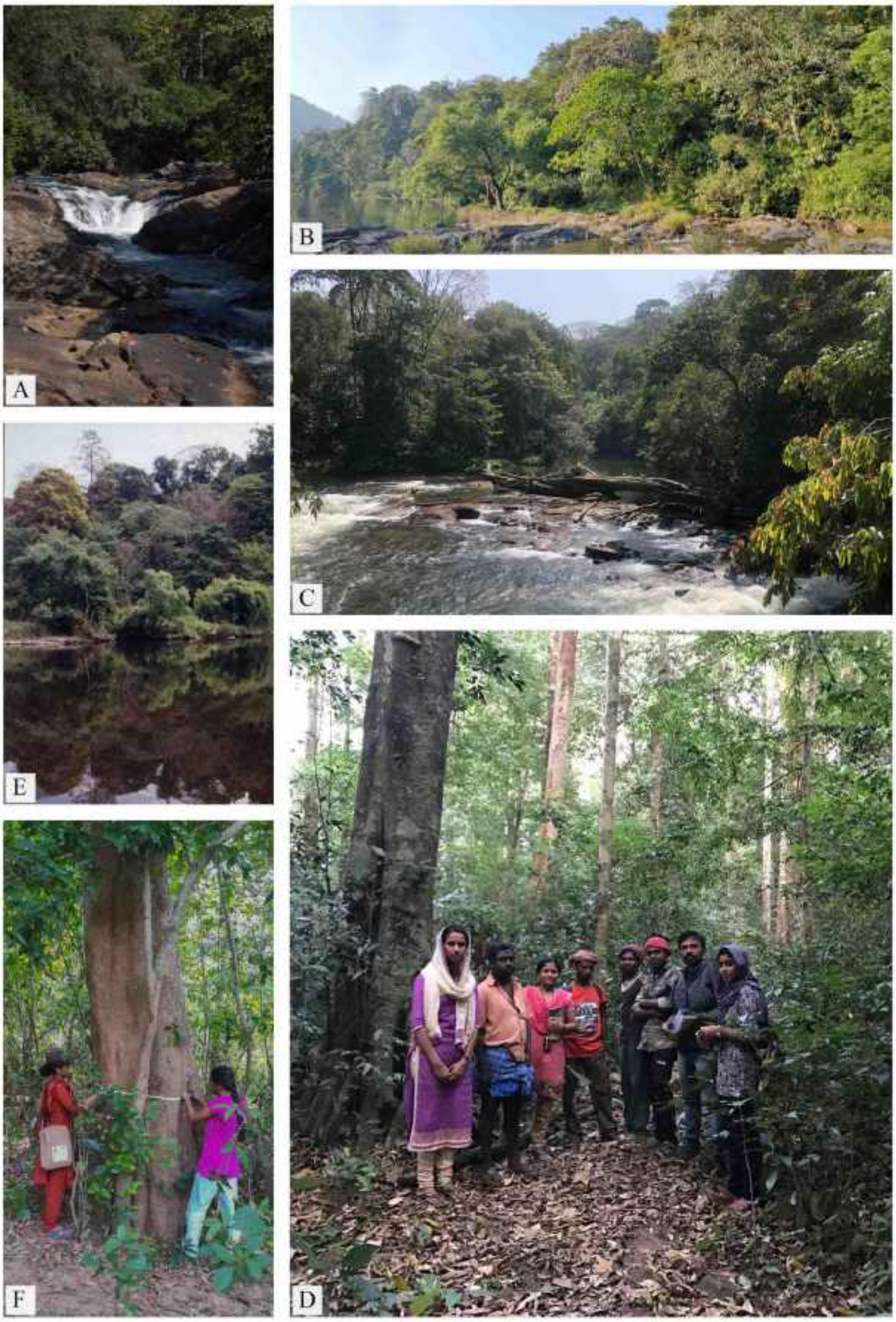


Fig. 5.6. T1.1.ii.Rp. Tropical Wet-Evergreen Riparian Forests (TWEvRp.): A. Nelliyampathy; B - D. Sholayar; E. Orukombankutty; F. Vazhachal.

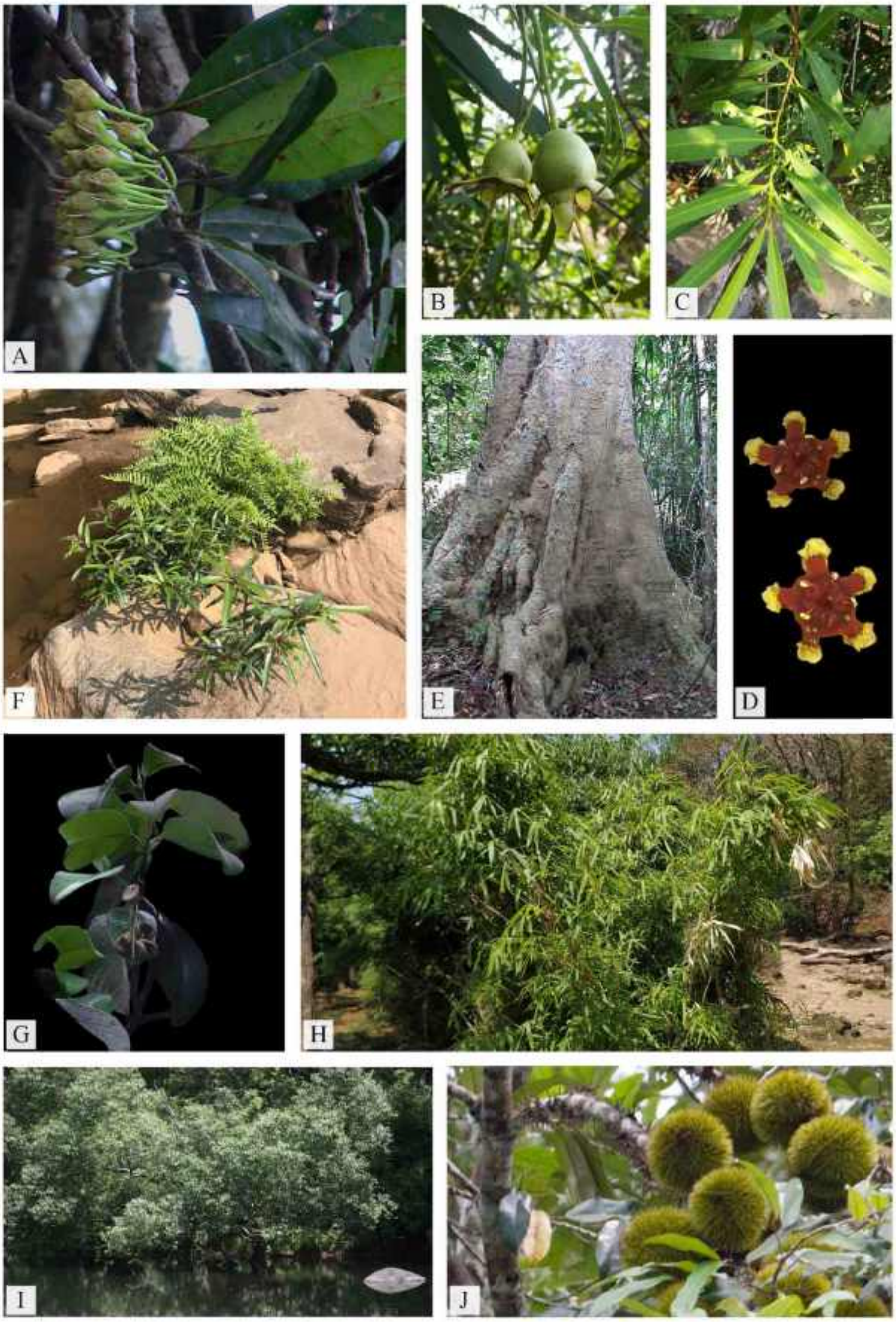


Fig. 5.7. T1.1.ii.Rp. Tropical Wet - Evergreen Riparian Forests (TWEvRp.): A. *Madhuca neriifolia* (Moon) H.J.Lam; B. & C. *Syzygium occidentale* (Bourd.) Gandhi, B. Fruit, C. Leaves; D. & E. *Lophopetalum wightianum* Arn., D. Bark, E. Flowers; F. *Homonoia riparia* Lour.; G. *Bhesa indica* (Bedd.) Ding Hou; H. *Ochlandra scriptoria* (Dennst.) C. E. C. Fisch.; I. *Salix tetrasperma* Roxb.; J. *Cullenia exarillata* A. Robyns.

Fig. 5.8. T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp.): A. Pooyamkutty River; B. Idamalayar River; C. Vazhachal; D. Periyar River near Thattekad; E. Thumboormuzhi; F. Periyar River near Poru waterfalls.

Fig. 5.9. T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp.): A. & B. *Humboldtia vahliana Wight.*, A. Inflorescence, B. Leaves; C. & D. *Vateria indica* L.; E. *Homonoia riparia* Lour.; F. *Cinnamomum riparium* Gamble.

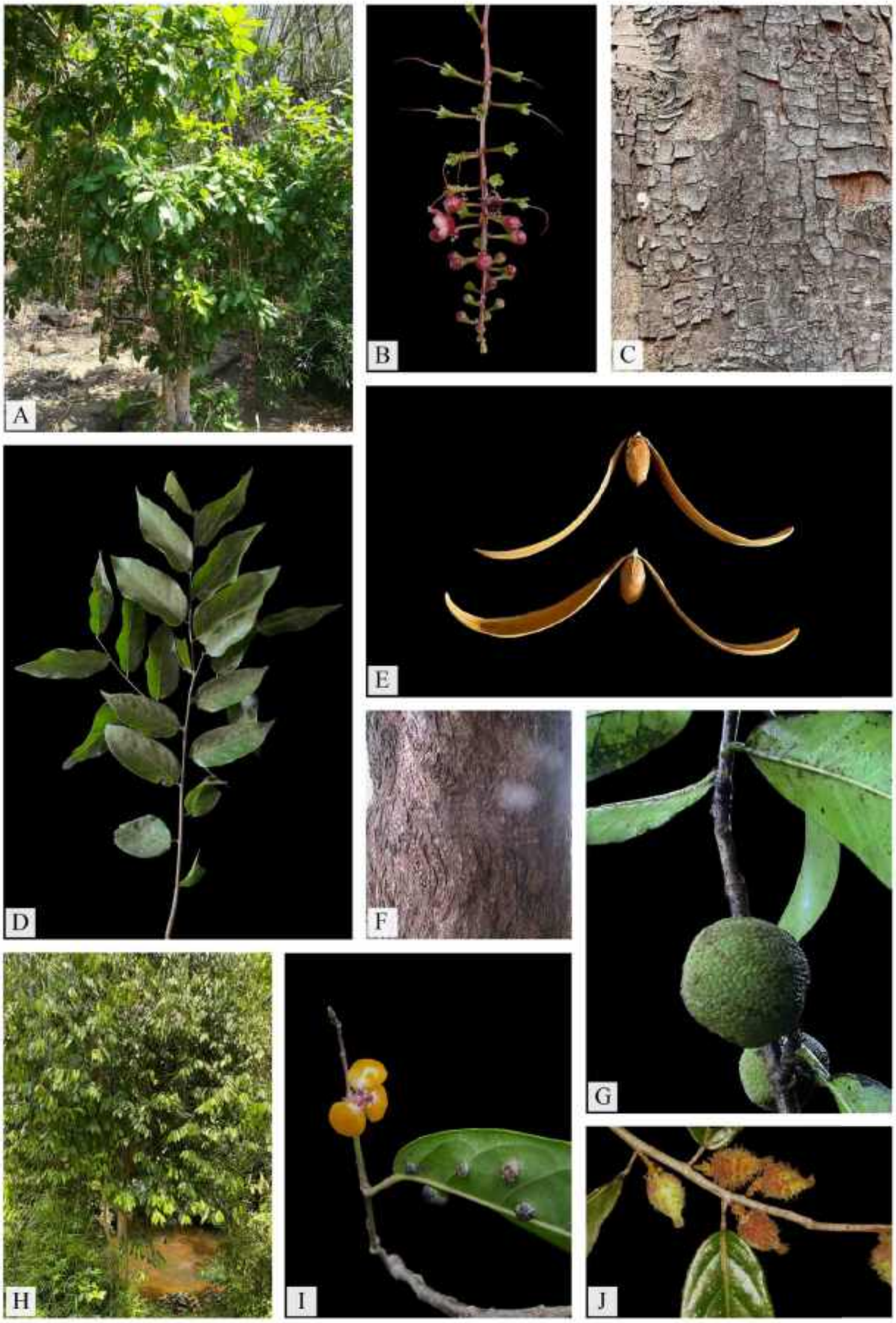


Fig. 5.10. T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp.): A.& B. *Barringtonia acutangula* (L.) Gaertn., A. Habit, B. Inflorescence; C., D., & E. *Hopea indica* (Raf.) R. Kr. Singh., C. Bark, D. Leaves, E. Fruit; F. & G. *Ochreinauclea missionis* (Wall. ex G. Don) Ridsdale., F. Bark, G. Fruit; H-J. *Aporosa bourdillonii* Stapf.

Fig. 5.11. T1.2. Rp. Tropical Dry Riparian Forest (TDRp.): A. Chinnar River; B. Pambar River at Champakkad; C-D. Field works in the riparian forests of Chinnar Wildlife Sanctuary.

Fig. 5.12. T1.2. Rp. Tropical Dry Riparian Forest (TDRp.): A.& B. *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.; C. & D. *Pongamia pinnata* (L.) Pierre., C. Fruiting branch, D. Inflorescence; E. & F. *Hopea indica* (Raf.) R. Kr. Singh., E. Fruit, F. Leaves; G. *Calophyllum calaba* L.; H. *Putranjiva roxburghii* Wall.; I. *Homonoia riparia* Lour.; J. *Mangifera indica* L.

Fig. 5.13. T1.3. Rp. Sub-tropical montane Riparian/ Streamside forests (TStMRp.): A-C. Nelliyampathy; D. Karappara; E. Aliyar; F. Munnar.

Fig. 5.14. T1.3. Rp. Sub-tropical montane Riparian/ Streamside forests (TStMRp.): A. *Elaeocarpus tuberculatus Roxb.*; B. *Debregeasia longifolia* (Burm. f.) Wedd.; C. *Ficus racemosa* L.; D. *Meliosma pinnata* (Roxb.) Maxim; E. *Ochlandra scriptoria* (Dennst.) C. E. C. Fisch.

5.3.c. Bioclimatic features of the cluster types

Analysing the distribution of identified riparian forest types within the mapped bioclimatic zones described in the present study (detailed in Chapter 3), it is revealed that all 20 recognised riparian forest subtypes within the Anamalai landscape exhibit bioclimatic traits that are consistent with a typical tropical climate, including T >15^{0}C (mean of the coldest month), R >1000-1500mm/year and Number of dry months <8 (Meher-Homji, 2001) except for the rainfall of Chinnar Valley, which is only 600 to 900 mm (TDRp Pa). The type T1.1i.Rp. Tropical Moist Deciduous Riparian Forests (TMDRp) are found along Elevation between 500-700 m, Rainfall >1500 mm, T>20^{0}C, Dry months = 4- 5.5 months, T1.1.ii.Rp. Tropical Wet-Evergreen Riparian Forests (TWEvRp) distributed along Elevation 500-1200 m, Rainfall >3000 mm, T>20^{0}C, Dry months 3- 4.2 months, T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp) span along Elevation 0-1000m, Rainfall >2000 mm, T>20^{0}C, Dry months 3-3.5 months, T1.2. Rp. Tropical Dry Riparian Forest (TDRp) is strictly found on Elevations 300-700 m, Rainfall <900 mm, T>23^{0}C, Dry months 6-7 months and T1.3. Rp. Sub-Tropical Montane Riparian / Streamside Forest (TStMRp) along Elevation above 1000 m, Rainfall >3000 mm, T<23^{0}C, Dry months 2-3 months.

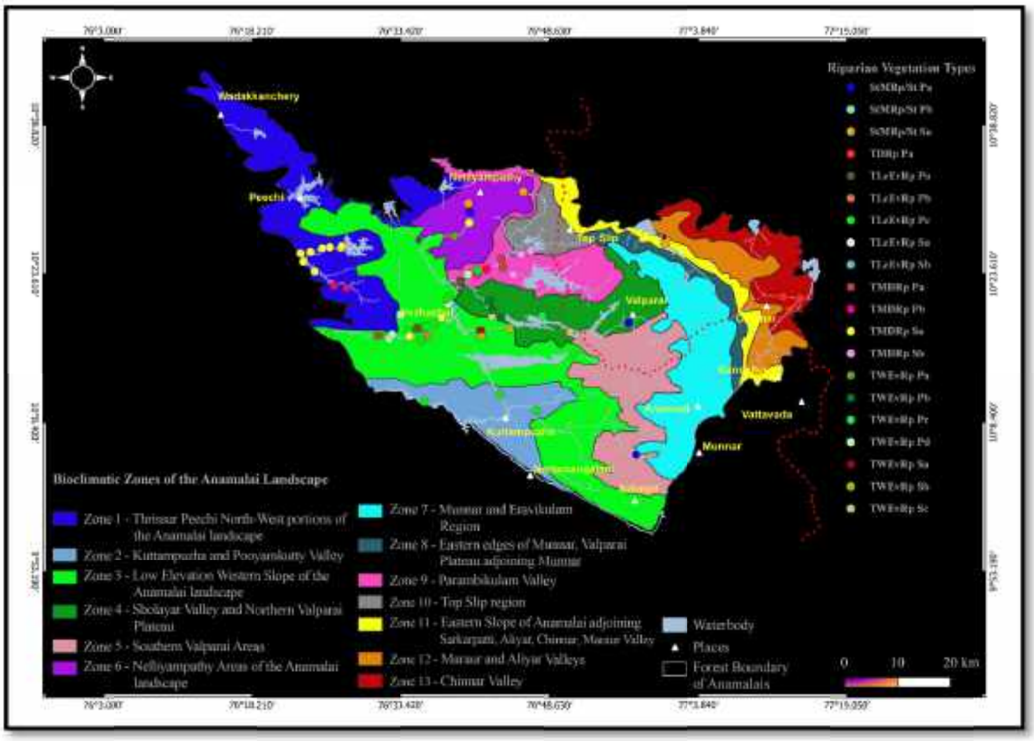


Fig. 5.15. Distribution of identified forest types across heterogenic bioclimatic zones of the Anamalai landscape

a) The bioclimaic Zone 1 - Thrissur Peechi North -West portions of the Anamalai landscape represent T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp).

b) Zone 2 - Kuttampuzha and Pooyamkutty Valley representing T1.1.iii. Rp. Tropical low elevation Evergreen Riparian Forests (TLeERp)

c) Zone 3 - Low elevation western slope of the Anamalai landscape with T1.1.iii. Rp. Tropical low elevation Evergreen Riparian Forests (TLeERp), T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp) and T1.1.ii.Rp. Tropical Wet-evergreen Riparian Forests (TWEvRp)

d) Zone 4 -Sholayar Valley and the Northern Valparai Plateau have the distribution of T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp) and T1.1.ii.Rp. Tropical Wet-evergreen Riparian Forests (TWEvRp)

e) Zone 6 - Nelliyampathy areas of the Anamalai landscape representing T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp), T1.1.ii.Rp. Tropical Wet-evergreen Riparian Forests (TWEvRp) and T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp)

f) Zone 9 - Parambikulam Valley has representations from T1.1.iii. Rp. Tropical low elevation Evergreen Riparian Forests (TLeERp), T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp) andT1.1.ii.Rp. Tropical Wet-evergreen Riparian Forests (TWEvRp)

g) Zone 10 - Top slip region showing the distribution of T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp)

h) Zone 13 - Chinnar Valley representing the T1.2. Rp.Tropical Dry riparian forest (TDRp) vegetation.

The remaining five bioclimatic zones: Zone 5 - Southern Valparai Areas, Zone-7 Munnar and Eravikulam region, Zone 8- Eastern edges of Munnar, Valparai plateau adjoining Munnar, Zone 11-Eastern slope of the Anamalai landscape adjoining Sarkarpatti, Aliyar, Chinnar and Maraur Valley, and Zone 12 - Maraur and Aliyar valleys are higher elevation area and hence do not have riparian forests which are represented only with Group 2. Montane Shola streamside/Evergreen riparian Forest (IV. 21. Rip.) (Bachan, 2010) coded here as T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp).

5.3.d. Floristic composition

Two hundred and fifteen tree species (215) belonging to 57 families and 146 genera were recorded from different bioclimatic sampling areas of riparian forests of the Anamalai landscape (Appendix VI). The most dominating family, Euphorbiaceae, had 13 genera and 22 species. Fabaceae is the second most prevalent family, with 13 genera and 16 species. Followed by Rubiaceae (9 genera and 9 species), Lauraceae (7 genera, 12 species), Sapindaceae (7 genera, 7 species), Anacardiaceae (5 genera, 6 species) and Clusiaceae (4 genera, 11 species) are the rich families based on the results of phytosociological analysis of the riparian zones of the Anamalai landscape (Fig. 5.16.). Appendix VII contains a comprehensive list of dominant families.

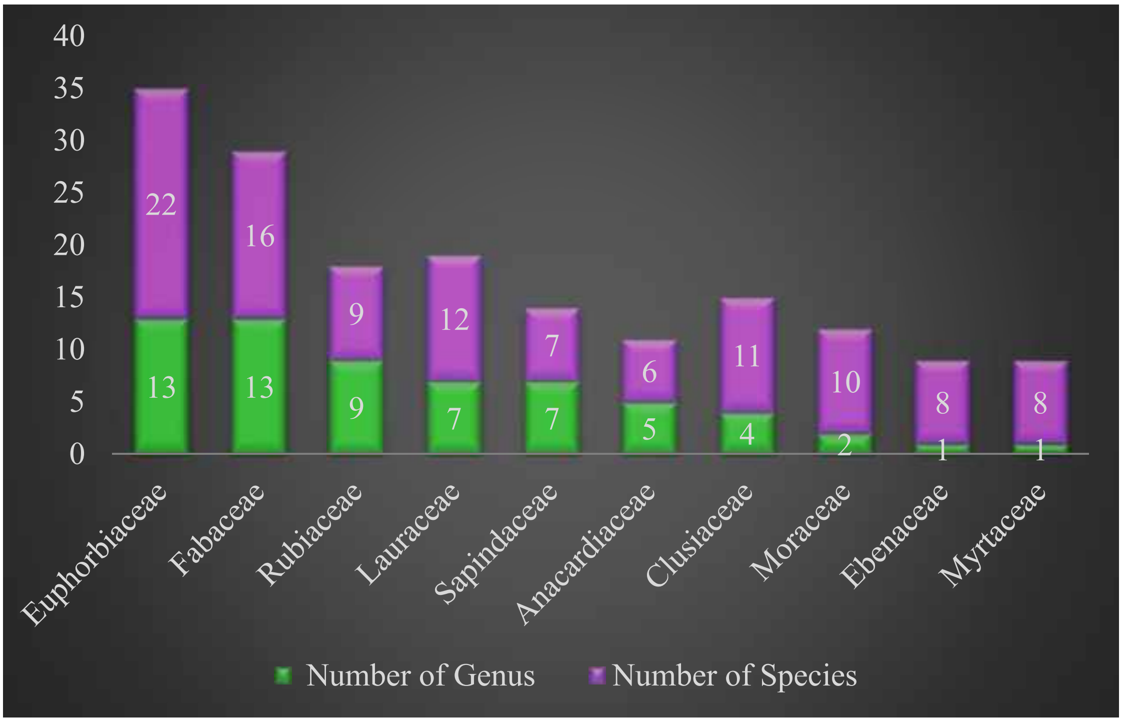


Fig. 5.16. Familywise number of genera and species identified from the riparian zone of the Anamalai landscape

5.3.e. Endemic and IUCN threatened categories of Anamalai landscape

Out of the 215 tree species that have been documented, 39 species belong to the IUCN threatened categories. The highest number of species falls under the vulnerable (VU) category of IUCN (19 Species), followed by the Endangered category (EN - 12 Species), Near threatened category (NT - 6 Species), and two critically endangered (CR) species *(Garcinia imbertii* and *Diospyros crumenata*) were recorded during the phytosociological study. A total of 64 endemic species were also recorded. A detailed list of endemic and IUCN-threatened categories of plant species from riparian forest enumeration of the Anamalai landscape is provided in Appendix VIII and Appendix IX, respectively.

5.3.f. Shannon diversity index, Simpson index and Evenness of riparian forest types within the Anamalai landscape

An essential indicator of a community's sustainability is the species diversity index. According to Pielou (1975), greater diversity is expected in a community with species distributed across various genera rather than one where most species are within the same genus. The value of the species diversity index generally increases as sample size increases (Vincy et al., 2014). Here, the study examines and compares identified riparian forest types using a range of ecological parameters, assessing the diversity and evenness of each type.

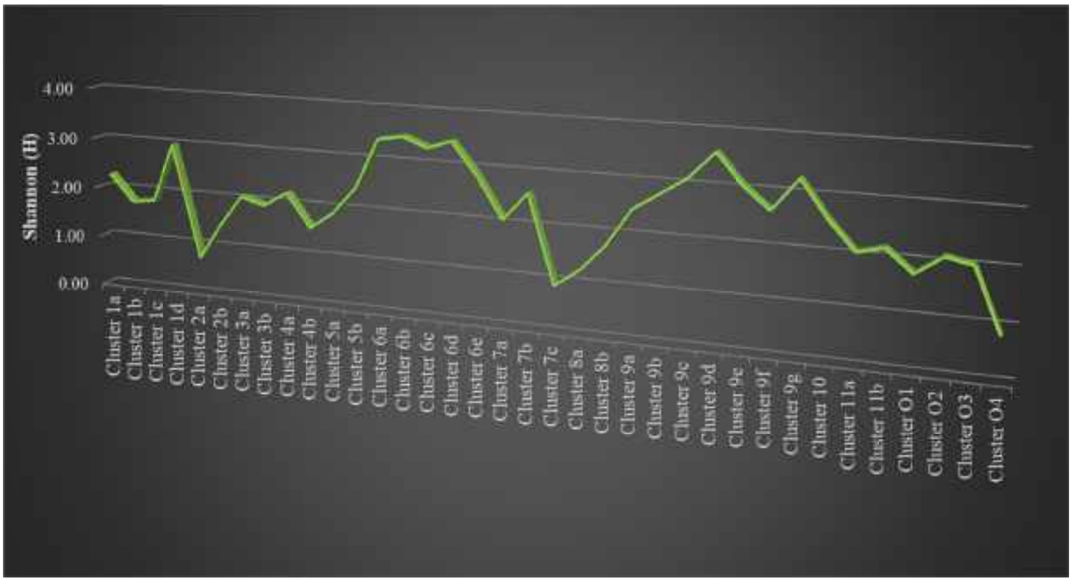


Fig. 5.17. Shannon diversity index (H) of identified forest types

Shannon Index (H) (Fig. 5.17.) indicates the richness of the evergreen riparian forest types. The greater the value of H', the greater the diversity of species in a given community. The lower the value of H', the less diverse the population. Shannon diversity Index (H') values exceeded 1 in thirty-three riparian clusters of the Anamalai Landscape. Cluster – 9d, TleEvRp Pa – Low elevation evergreen riparian forest had the highest Shannon Index (H' = 3.603) while cluster – 2a (TMDRp Sa – Secondary Moist Deciduous Riparian) had the lowest (H'= 0.7198).

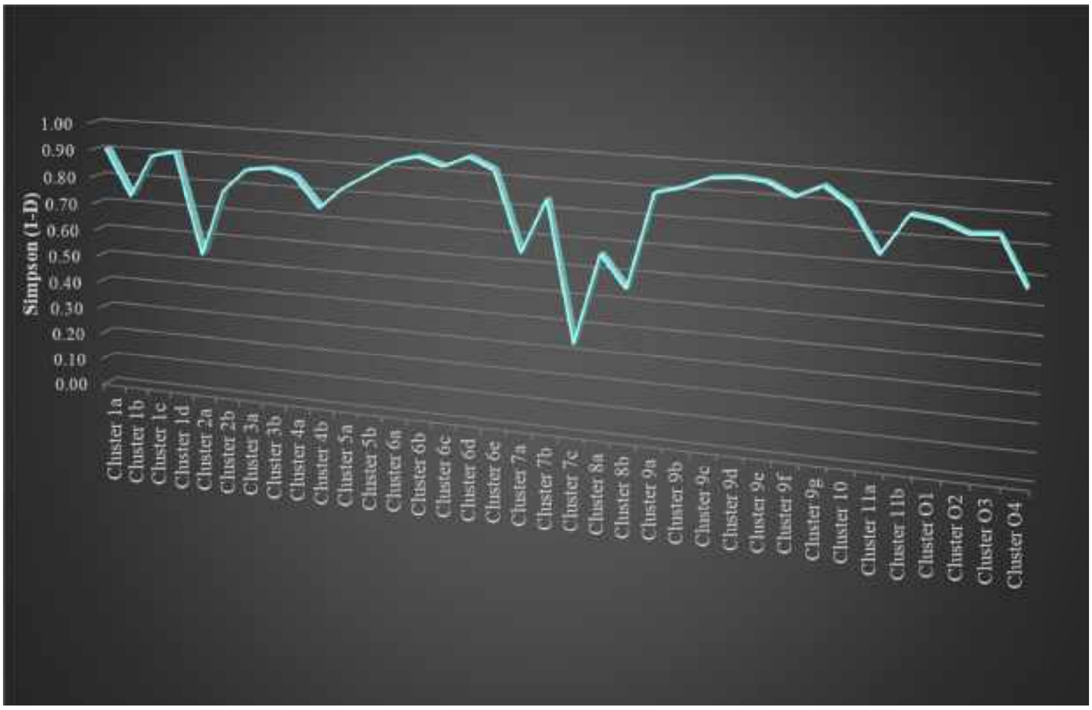


Fig. 5.18. Simpson index (1-D) of identified forest types

The Simpson Index for negative dominance (Fig. 5.18.) was maximum for cluster – 6d, TleEvRp Pb – Low elevation evergreen riparian forest (0.9674) while cluster – 7c, TWEvRp Pd – Wet evergreen streamside riparian forest had the lowest (0.3335).

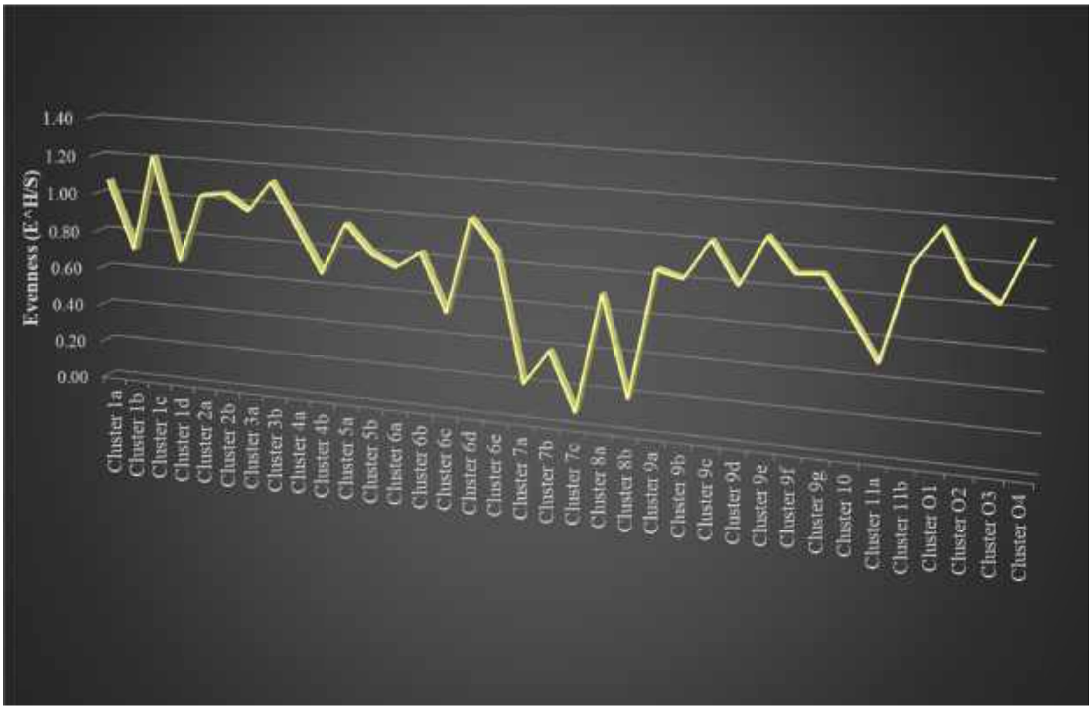


Fig. 5.19. Evenness(e^H/S) of identified forest types

Species evenness is a metric for species' relative abundance. The higher the evenness value, the more uniformly the species are distributed (Devlin & Singh, 2018). Here, (Fig. 5.19.) TMDRp Pb – Moist deciduous riparian forest (Cluster 1c) had the highest Evenness (e^H/S -1.214), while TWEvRp Pd – Wet evergreen streamside riparian forest (Cluster 7c) had the lowest Evenness (e^H/S – 0.07944). This indicates the dominance of certain species and less diversity in these riparian forest types.

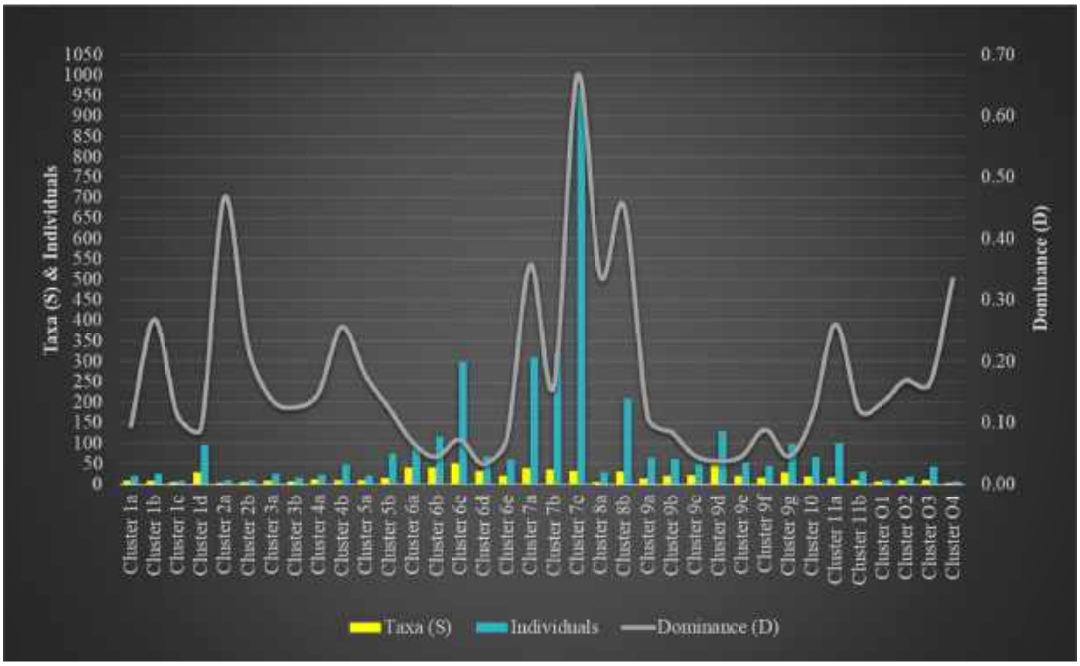


Fig. 5.20. Taxa (S), Individuals and Dominance (D) of identified forest types

The number of Taxa (S) identified is minimal for TMDRp Sa – Secondary moist deciduous riparian forests (Cluster 2a and Cluster O4) with 3 Taxa and maximal for Cluster 6c (TleEvRp Pc – Low elevation evergreen riparian forest – 51 Taxa). The maximum number of individuals was discovered for Cluster 7c (TWEvRp Pd – Wet (Moist) Evergreen streamside riparian forest – 966 individuals), and the least was found for Cluster O4 (TMDRp Sa – Secondary moist deciduous riparian forests – 7 individuals). Also, TWEvRp Pd – Wet Evergreen streamside riparian forest (Cluster 7c) had the highest Dominance (D) value (0.6665) contributed by the highest dominance of *Ochlandra scriptoria* than other species representing the type and lowest Dominance (D) found for TleEvRp Pb – Low elevation evergreen riparian forest (Cluster 6d – 0.03256) (Fig. 5.20.). A detailed table of each parameter for all the identified forest types is provided in Appendix X.

5.4. Discussion

5.4.a. Community compositions and classification of riparian forests

As previously noted by the studies of Meher-Homji (2001) and Bachan (2010), all 36 recognised forest types within the Anamalai landscape exhibit tropical climate. Similar bioclimate-based vegetation studies, especially in the riparian forest areas of the Indian region, are exceedingly rare, except for the study by Bachan (2010), who identified 18 cluster types and classified them into 4 vegetation types and 11 subtypes from four varying bioclimates of Chalakudy basin alone. The 36 identified vegetation types from different bioclimatic zones of the Anamalai landscape serve as an extension of the study by Bachan (2010) to the other bioclimatic regions of the Anamalai landscape.

The latest classification of Riparian forest types in the Western Ghats by Bachan et al. (2022) and Bachan (2023) identifies 44 riparian forest subtypes across the Western Ghats under 3 major riparian forest types. Following this classification, the present study identified 20 riparian forest types from the riparian zones of the Anamalai landscape under 3 major riparian forest types T1.1. Rp. Tropical Moist Riparian Forest, T1.2. Rp. Tropical Dry Riparian Forest (TDRp), and T1.3. Rp. Sub-Tropical Montane Riparian/ Streamside Forest (TStMRp). All belong to the Dry and Moist Forest types of Champion and Seth (1968). The highest number of riparian vegetation subtypes represented from the type T1.1.ii.Rp. Tropical Wet-Evergreen Riparian Forests (TWEvRp) (7 subtypes) and the T1.2. Rp. Tropical Dry Riparian Forest (TDRp) has the least subtypes (1 subtype) within the landscape boundary. Table 5.5. provide a comparison between riparian forest types in the Anamalai landscape and Western Ghats.

Table 5.5. An overview of riparian forest classification of the Anamalai landscape

Biome	Riparian Forest Type		Riparian forest subtypes of Anamalai Landscape	Riparian forest subtypes of Western Ghats Bachan (2023)
T1 – Tropical Subtropical Forest Biome	**T1.1. Rp. Tropical Moist Riparian Forest**	T1.1i.Rp. Tropical Moist Deciduous Riparian Forests (TMDRp)	4 subtypes	6 subtypes
		T1.1.ii.Rp. Tropical Wet-Evergreen Riparian Forests (TWEvRp)	7 subtypes	15 subtypes
		T1.1.iii. Rp. Tropical Low Elevation Evergreen Riparian Forests (TLeERp)	5 subtypes	12 subtypes
	T1.2. Rp. Tropical Dry Riparian Forest (TDRp)		1 subtype	6 subtypes
	T1.3. Rp. Sub-Tropical Montane Riparian/ Streamside Forest (TStMRp)		3 subtypes	5 subtypes

All of the ensuing vegetation types in the Anamalai landscape's bioclimatic zones reflected various stages of primary and secondary communities corresponding to the four major tropical moist forest types outlined by Meher-Homji (2001) and the Champion and Seth (1968) Dry and Wet Forest Types. Most of the wet evergreen riparian forest types of the Anamalai landscape are represented in the Sholayar tributary of Chalakudy River (TWEvRp Pb., TWEvRp Pc., TWEvRp Pd. TWEvRp Sa., TWEvRp Sb., and TWEvRp Sc.). The figures showing the dominant species associations of the Wet evergreen types of the Sholayar River are provided in Fig. 5.21. To Fig. 5.25.

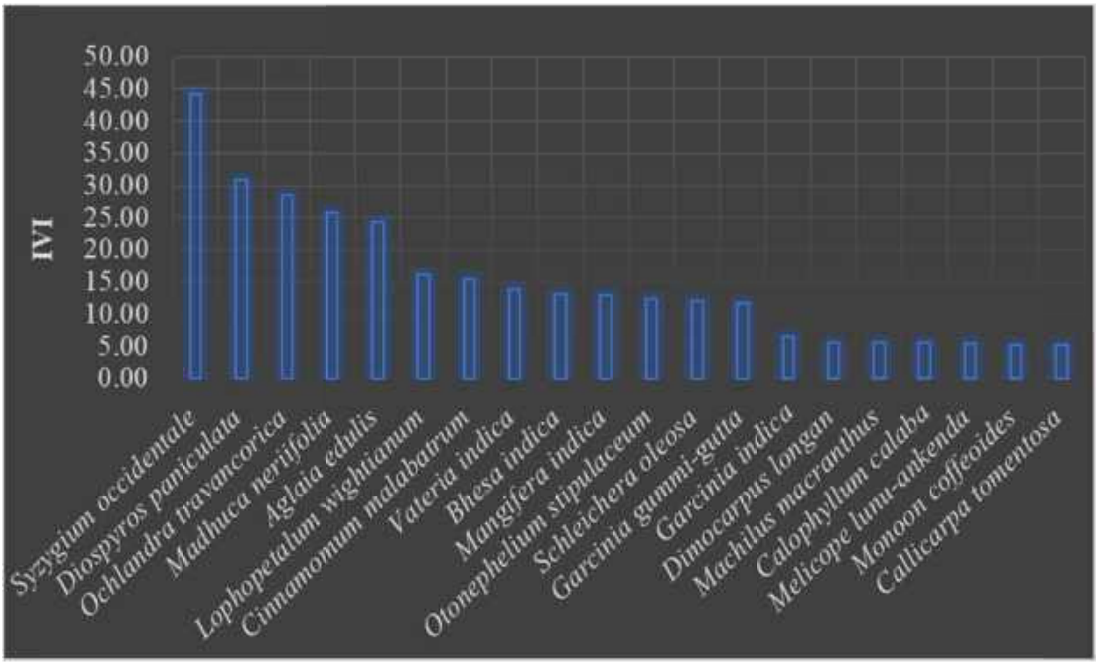


Fig. 5.21. IVI of riparian tree species in the TWEvRp Pb - Wet (Moist) evergreen riparian forest (Cluster 9b)

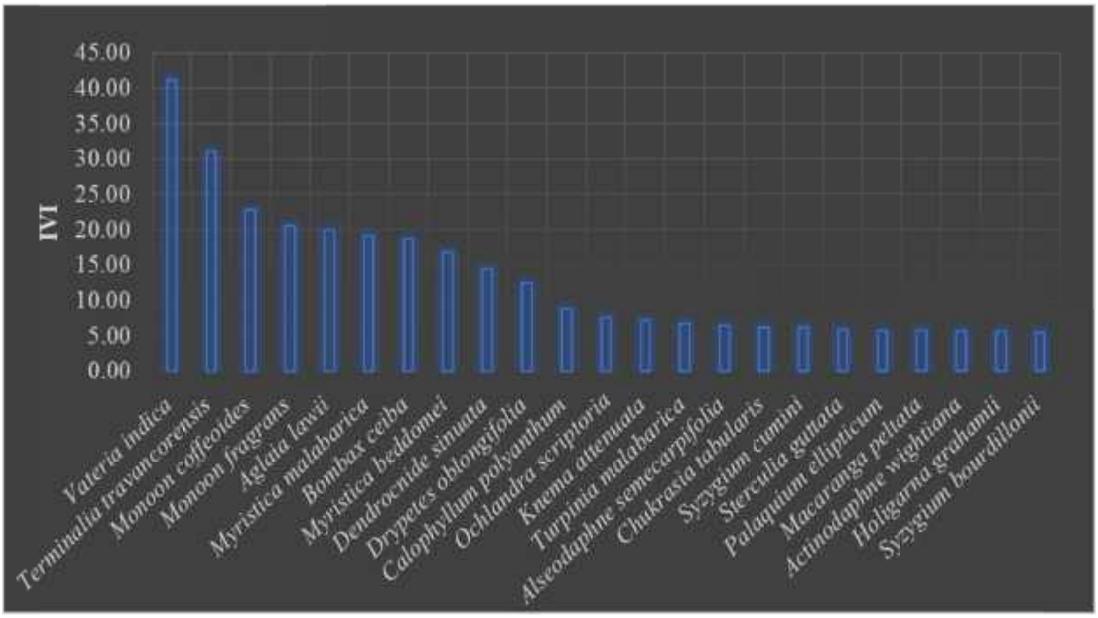


Fig. 5.22. IVI of riparian tree species in the TWEvRp Pb - Wet (Moist) evergreen riparian forest (Cluster 9c)

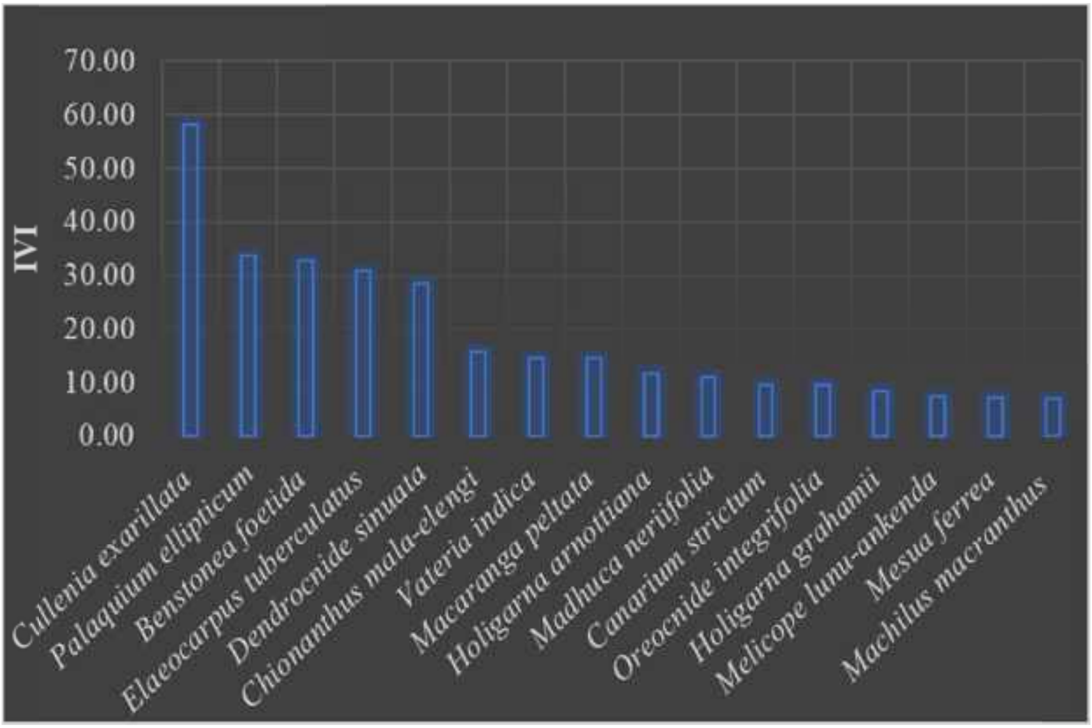


Fig. 5.23. IVI of riparian tree species in the TWEvRp Pc - Wet (Moist) evergreen riparian forest

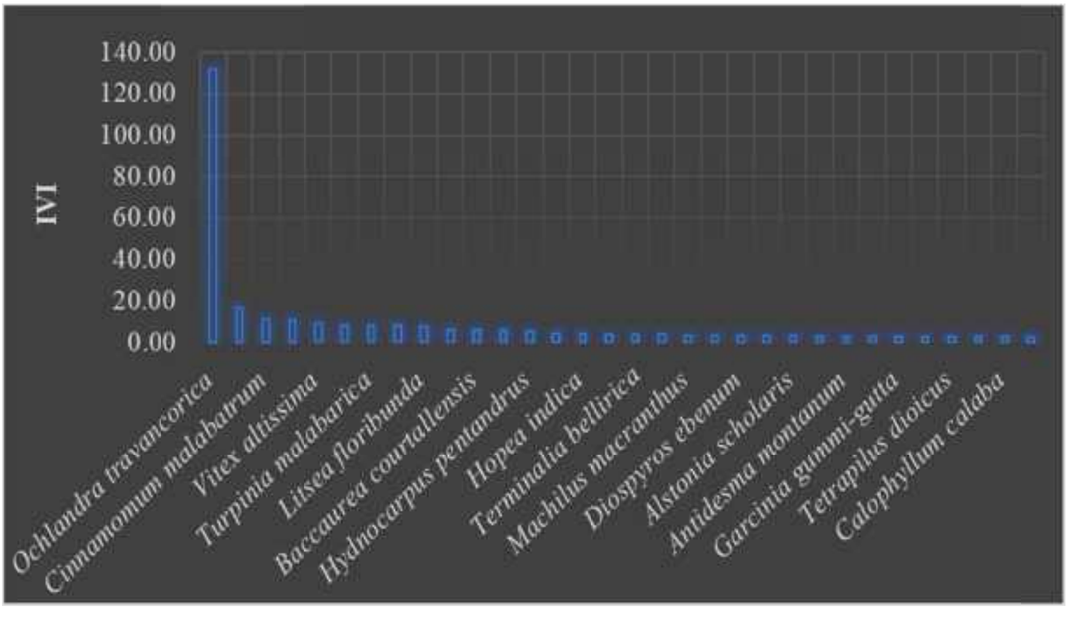


Fig. 5.24. IVI of riparian tree species in the TWEvRp Sb - Secondary semi-evergreen riparian forest

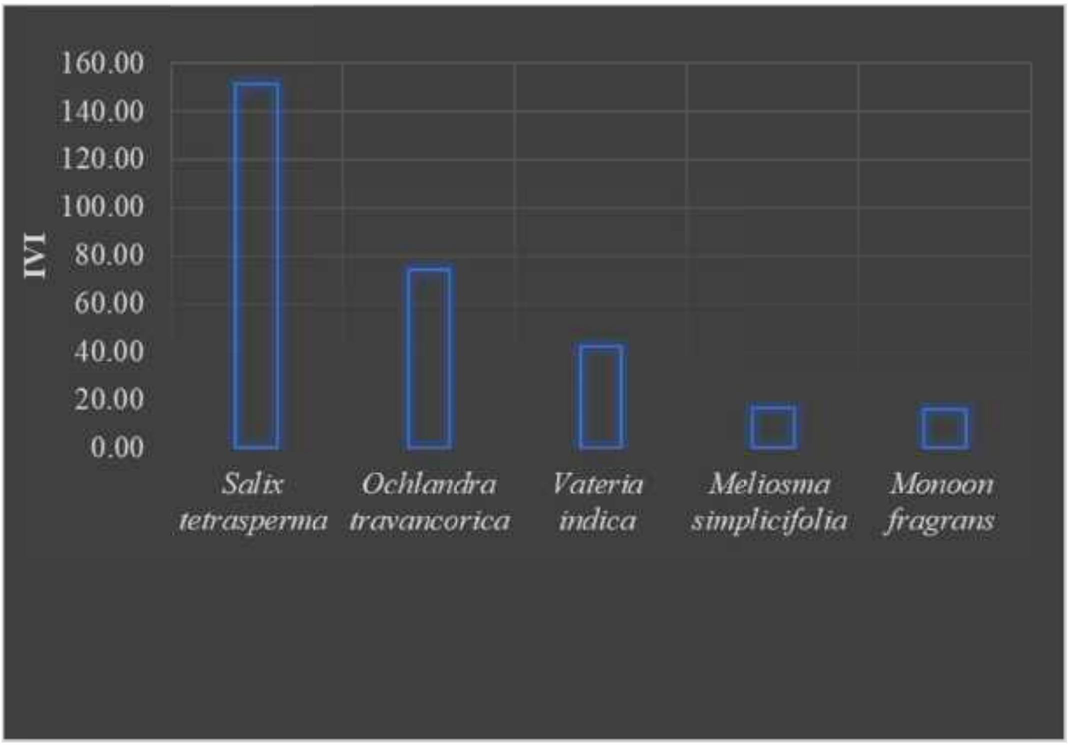


Fig. 5.25. IVI of riparian tree species in the TWEvRp Sc - Secondary semi-evergreen riparian forest

The Southern Western Ghats critically endangered low-elevation riparian forest, and predictions made by (Bachan et al., 2022) about the favourable bioclimatic areas detected from low-elevation riparian forest habitats in the Chalakudy River (Athirappilly Vazhachal region) and also from lower areas of Periyar (Idamalayar and Pooyamkutty valleys) from the Anamalai landscape. Riparian forest types explained by Bachan (2010): Group I. Moist deciduous riparian forest, Group II. Montane Shola streamside/Evergreen riparian vegetation, Group III. Evergreen riparian vegetation, Group IV. Moist Evergreen Riparian Forest types represented in this study as T1.1i.Rp. Tropical Moist Deciduous Riparian forests (TMDRp), T1.3. Rp. Sub-tropical montane riparian/ streamside forest (TStMRp), T1.1.iii. Rp. Tropical low elevation Evergreen Riparian Forests (TLeERp), T1.1.ii.Rp. Tropical Wet-evergreen Riparian Forests (TWEvRp) respectively. There have been reports of similar forest types in the Cauvery Basin riparian areas belonging to the dry bioclimatic group T1.2. Rp. Tropical Dry Riparian Forest-TDRp with *Terminalia arjuna* dominance (Sunil, 2012) (Fig.5.26).

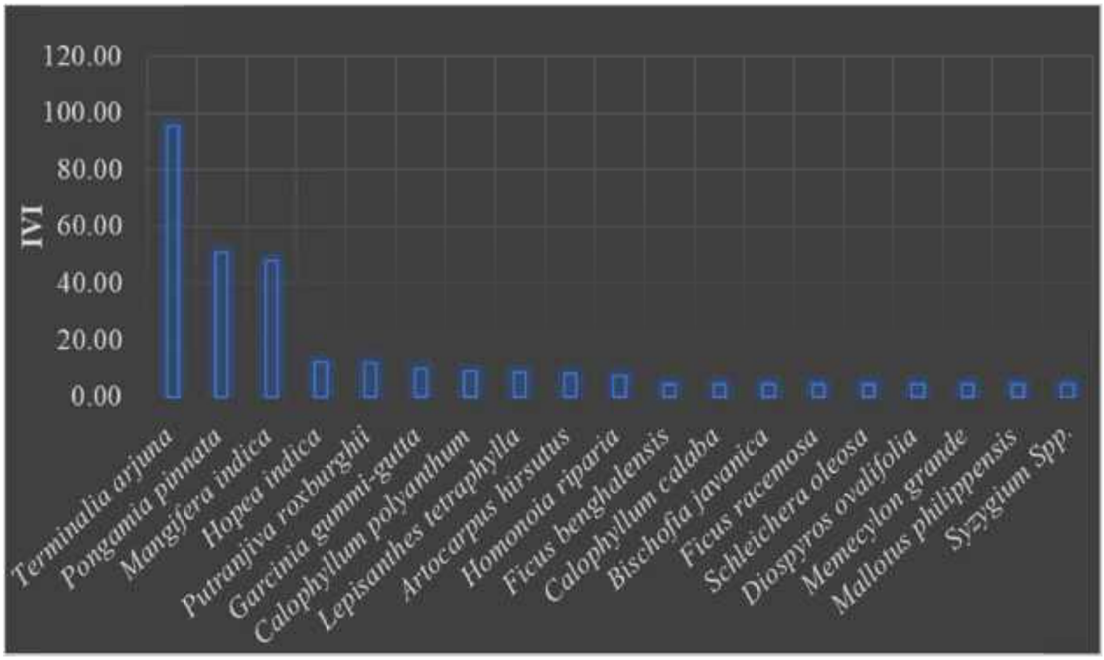


Fig. 5.26. IVI of riparian tree species in the T1.2. Rp. Tropical dry riparian forest (TDRp)

The riparian vegetation types described in the present study also differed from earlier studies along the Chalakudy River (Bachan, 2010), Pamba River (Joby, 2012), and Valapattanam River (Sreedharan, 2005) of Kerala due to the absence of mangrove elements in the species composition especially near the flood plains, this is because the Anamalai landscape boundary did not encompass the extreme lowland sampling regions (>100m.). Except for the classification of the Chalakudy basin by Bachan (2010), which served as the foundation for the current study, no comparable classification systems for riparian forests have yet emerged from the Indian region. Moreover, the riparian forest types are not adequately represented in Champion and Seth's (1968) classification of vegetation types in India. The only riparian vegetation types mentioned in Champion and Seth's (1968) updated Forest Classification are the dry type 5/ISI - Dry Tropical Riverain Forest and the moist type 4 E/RS1- Tropical riparian fringing forest. Based on data available for Dry Bioclimate *Terminalia arjuna* and *Lagerstroemia speciosa* as characteristic species, the Moist type riparian fringing forests (4 E/RS1) were categorised under Littoral and Swamp forest. However, riparian zones on the heavily forested western slope of the Southern Western Ghats have a distinct pattern. He has indicated that additional data is necessary to comprehensively describe the Dry tropical riverain forest from South India since it is more distinctive (Pg: 173- Champion & Seth, 1968). By providing acceptable descriptions of the riparian forest classification, the present study addressed the gap left by Champion and Seth (1968), which is inadequate to explain the riparian vegetation in the moist areas of the heavily rainfed western slopes of the Western Ghats.

5.4.b. Shannon diversity Index, Simpson Index, and Evenness of Riparian forests

The present study results reveal that within the riparian forest types of the Anamalai landscape, maximum Shannon diversity was shown by the forest type Tropical low elevation evergreen riparian forest -TLeEvRp Pa (3.6) and the lowest by Secondary moist deciduous riparian - TMDRp Sa (0.71). These findings agree with the results of the previous study from the Chalakudy basin (Bachan, 2010), with the highest diversity of the Evergreen riparian low-elevation forests (1.618). In contrast, the lowest diversity is shown by the Secondary semi-evergreen degraded riparian forest (0.466). Also, Bachan (2010) identified Primary moist deciduous riparian forests and wet evergreen riparian forests as the second most diverse group of riparian ecosystems of the Chalakudy River. However, in the present study, TStMRp/St Pb - Montane evergreen riparian forest and TWEvRp Pb - Wet (Moist) evergreen riparian forests exhibit higher diversity than Moist deciduous riparian forests. Other riparian studies also attest to the most remarkable diversity of Low elevation evergreen riparian forests (Sundarapandian & Swamy, 1997; Gaston, 2000; Osborne, 2000; Ramesh & Gurukkal, 2007; Pooja et al., 2020; Bachan et al., 2022).

In contrast to this Kumara and Srikantaswamy (2011) show that the Shannon index was found to be maximum (3.6) in upstream regions of the Tungabhadra River in Karnataka, which was higher than in downstream portions; the Meenachil River basin's upstream riparian zone has the highest species diversity and richness (Vincy et al., 2014; Devlin & Singh, 2018) With the lowest Shannon index (0.73) in the lower zone and the highest Shannon index (1.25) in the middle zone. Some studies reported Shannon index values lower than the present study (Natta, 2000; Burton et al., 2005; Holmes, 2008; Iqbal et al., 2012; Joby, 2012; Packiaraj & Kannan, 2014; Vincy et al., 2014; Mohanan, 2023; Packialakshmi et al., 2023). Moreover, some reported higher (Pascal, 1988; Vidyasagaran et al., 2000; Sunil et al., 2016; Shruti et al., 2019). When compared to Pascal and Pelissier (1996), the Shannon diversity of Tropical low-elevation evergreen riparian forests (Shannon index = 3.6 and Simpson index = 0.96) is lower than that of Western Ghats Wet evergreen forests (Shannon index = 4.56 and Simpson index = 0.92) but more significant for the Simpson index. Tripathi and Singh (2009) suggested that enhanced soil moisture and nutrients were to account for the high species richness in riparian forests.

The value obtained for the Simpson diversity index in the present study is maximum for Tropical Low elevation evergreen riparian forests (0.96) and minimum for Tropical moist deciduous forests (0.53) and Wet (moist) evergreen streamside riparian forests (0.33). This range is similar to the observations made by Sunil et al. (2016) from riparian forests of the Cauvery basin (0.96); Sakthivel et al. (2019) in riparian forests along the Amirthi River of Tamil Nadu (0.95 to 0.96); From the Pamba river basin (0.94–1.0) by Joby (2012). Moreover, the Simpson diversity index appears less than the riparian forests of the Anamalai landscape in some other riparian investigations (Vidyasagaran et al., 2000; Iqbal et al., 2012).

In the Anamalai landscape, maximum Evenness (e^H/S) was shown by Moist deciduous riparian forests (1.21) and least for Wet (moist) evergreen streamside riparian forests (0.07). The difference in soil condition and disturbance patterns may be the reason for the high evenness value of Moist deciduous riparian forests. Comparable evenness scores are observed from the studies of Devlin and Singh (2018) from the Dikhu River of Nagaland (0.47-0.37); Sakthivel et al. (2019), from Amirthi River, Tamil Nadu (0.53 to 0.58); Sunil et al. (2016) from Cauvery River basin (0.83); Packialakshmi et al. (2023) for the tree layer in the Nilgiris Biosphere Reserve (0.40); Holmes (2008) For Northeastern Ohio, (0.73 to 0.85); Burton et al. (2005) from riparian areas of urban and rural areas within the sections of Muscogee and Harris (0.69 to 0.81). The Evenness scores for the Moist deciduous riparian forest (1.21) of the present study are nearly identical to those of Iqbal et al. (2012) for tree species Khok River of Garhwal Himalaya, with Evenness values ranging from 1.11 to 0.95.

The current findings are consistent with the work of several riparian ecologists who have found comparable differences in vegetation along river corridors. The result is in line with the findings of Joseph (2009) based on Shannon and Simpson diversity indices, which revealed that, compared to other forest types, evergreen forests were highly diverse, with lower levels of dominance. Secondary Moist Deciduous Riparian types in the present study showed a decline in Shannon and Simpson diversity, which is consistent with findings from other research works that also evidenced a decline in H' in disturbed areas (Sibanda et al., 2014; Takarina et al., 2021). However, Nurika et al. (2019) concluded that Diversity index values were sometimes relatively low in communities that had reached a climax. Hence, as Sambare et al. (2011) concluded, the phytogeographical gradient, the water regime, and the channel width of the watercourse influence species richness, taxonomic diversity, species diversity, and the stand structure.

According to the findings of the current study, the riparian forests are significantly impacted by adjacent land use patterns, including deforestation and degradation of the nearby vegetation, anthropogenic disturbances such as grazing, agriculture, exploitation, and erosion, As evidenced by the Secondary dry deciduous riparian forest of the Parambikulam basin due to nearby plantation areas, Secondary semi-evergreen riparian forest within the wet evergreen bioclimate of Anamalai landscape (Chalakudy and Periyar basin) and Montane Shola Streamside degraded riparian forest of Nelliyampathy due to Tea, Coffee, and Cardamom plantations, lack of native riparian forests due to highly modified riparian zones by human land-uses. (Kechery, Karuvannur, and Aliyar riparian zones). Thus, the networks of surviving riparian forests can only contribute to maintaining the region's diversity.

5.5. Summary

In the riparian forest of the Anamalai landscape, this study offers a critical investigation of the richness of riparian tree species. Although from the various bioclimatic stratified random sampling riparian zones alone, 215 distinct species of trees were identified, spanning 57 families and 146 genera, in which 64 species belong to the endemic category and 39 species of IUCN threatened category that reflects the diversity and significance of the riparian zones of the Anamalai landscape. The analysis identifies 11 major cluster groupings, 32 sub-clusters, and four odd clusters from the Anamalai landscape at various similarity coefficient values. All the clusters were individually evaluated for dominating community relationships using IVI. and successfully classified into three major (T1.1. Rp.

Tropical Moist Riparian Forest, T1.2. Rp. Tropical Dry Riparian Forest (TDRp), and T1.3. Rp. Sub-Tropical Montane Riparian/ Streamside Forest (TStMRp)) and twenty subtypes as per the riparian forest classification given by Bachan et al. (2022) and Bachan (2023) under the Tropical subtropical forest biome of Keith et al. (2020). A detailed classification is given, with the forest-type Tropical low-elevation evergreen riparian forest showing the highest Shannon and Simpson diversity indices and Secondary moist deciduous riparian forests with the lowest.

The research demonstrates that the Anamalai landscape riparian forest has a wide diversity of trees that serve as a habitat and food source for many riparian-dependent species. However, the population structure and ecological functioning of Anamalai landscape riparian zones are threatened by anthropogenic activities, which are especially prominent in the lower region of each basin and agriculture and plantation operations up to the riparian zones of rivers. As a result, Anamalai landscape riparian zones require comprehensive management and restoration strategies since the existing trends will influence the structure, composition and regeneration of the riparian forests and accelerate the degradation of the surviving primary forest types.

Chapter - 6

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SUMMARY AND CONCLUSION

Riverbank forests are an essential element of a landscape that links the many ecosystems and their fauna, and riverbanks are the sites of human cultural and historical centres. Within 4200 km^2 in the southern region of the Western Ghats, the Anamalai landscape comprises rivers of higher, medium, and low elevations. It includes six major river basins (Chalakudy, Periyar, Pambar, Bharathapuzha, Karuvannur, and Kechery). The landscape has a tropical climate, and the eastern slopes are in the rain shadow region, whereas the western slopes receive the highest rainfall. The landscape represents bioclimatic variations across the eastern and western slopes and shows high rainfall fluctuation. Thus, the study gives special emphasis on the delineation of bioclimate, riparian vegetation mapping, identification of riparian community compositions, and their classification within the Anamalai landscape. The application of GIS techniques, along with field sampling, as well as the data collected from meteorological sources, form the basis of the present work.

6.1. The bioclimatic zones and riparian forests cover of the Anamalai landscape

Bioclimatic zonation of a complex landscape like Anamalai, especially from the Southern Western Ghats, is a first attempt. The bioclimatic analysis brings out thirteen different bioclimatic zones across the Anamalai landscape with characteristic variations in Mean annual Temperature (^{0}C), Average Rainfall (mm) and Number of Dry Months following the methods used by Bagnouls and Gaussen (1953), Mehr-Homji (2001) and Bachan (2010).

a) Zone 1- Thrissur Peechi North -West portions of Anamalai landscape
b) Zone 2-Kuttampuzha and Pooyamkutty Valley
c) Zone 3- Low elevation western slope of Anamalai landscape
d) Zone 4- Sholayar Valley and Northern Valparai Plateau
e) Zone 5- Southern Valparai Areas
f) Zone 6- Nelliyampathy areas of the Anamalai landscape
g) Zone 7- Munnar and Eravikulam region
h) Zone 8- Eastern edges of Munnar, Valparai plateau adjoining Munnar

i) Zone 9-Parambikulam Valley

j) Zone 10- Top slip region

k) Zone 11- Eastern slope of Anamalai landscape adjoining Sarkarpatti, Aliyar Chinnar and Maraur Valley

l) Zone 12- Maraur and Aliyar valleys

m) Zone 13-Chinnar valley

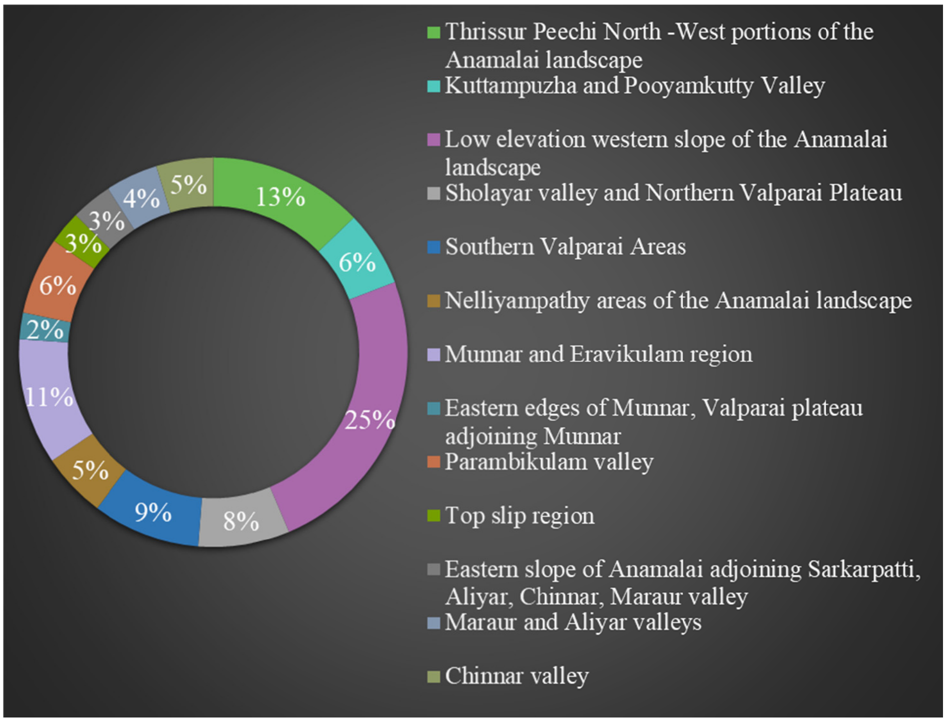

Fig. 6.1. Area of bioclimatic zones (%) within the Anamalai landscape.

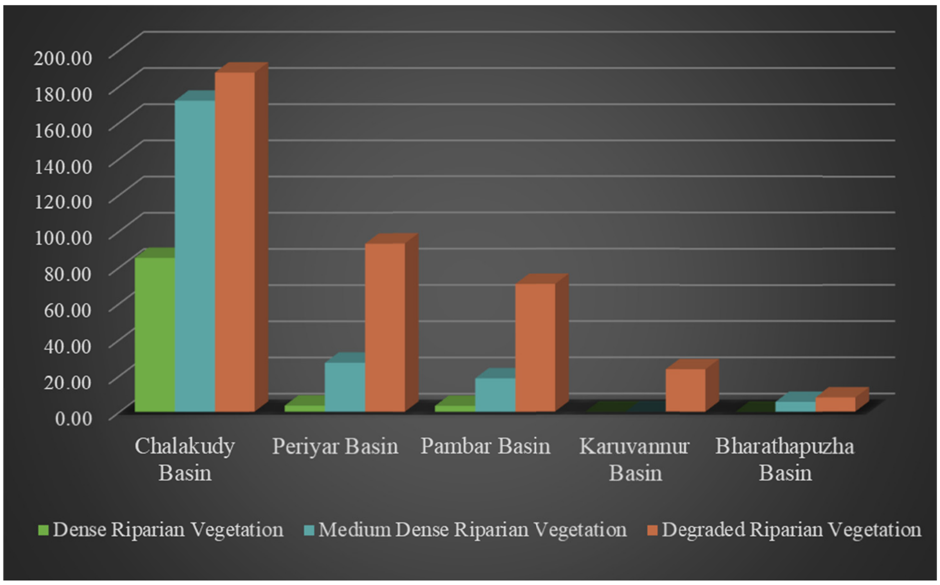

Fig. 6.2. Summary of riparian forests cover of the Anamalai landscape (ha)

The riparian forest maps of the Anamalai landscape developed using Google Earth Pro and QGIS 3.22 open-source software were the first attempt, especially from the Western Ghats. The study delineates the boundary of the Anamalai landscape, covering an area of 4200 km^2 according to cartography. The different riparian forest types have been identified by visual interpretation methods using Google Earth Pro and QGIS 3.22 software. The mapping of the riparian forests of the Anamalai landscape shows that there are 697.06 hectares of riparian forests within the 4200 km^2 area of the Anamalai landscape. The riparian forests are composed of 13.17 % (91.79 ha) of dense forests, 32 % (223.05 ha) of medium dense forests, and 54.83 % (382.23 ha) of degraded forests.

The bioclimatic zone 3- Low elevation western slope of the Anamalai landscape (354.28 ha) supports the highest riparian area. The Chalakudy basin covers the highest riparian forests (444.59 ha) and also the highest in dense riparian cover (85.10 ha). In contrast, the Bharathapuzha basin has the highest bioclimatic variations (9 zones) even though it has the least riparian forest cover (13.31 ha) because it has only a single tributary inside the landscape boundary (Aliyar River – 9.59 km), with less potential riparian zone (57.54 ha) and the degradation of the existing riparian zones. Chimmony and Mupli rivers of Karuvannur Basin, have highly degraded riparian forests due to monoculture plantations in the riparian zone. Kuriyarkutty River of the Chalakudy basin is the lowest in riparian forest cover (7.87 ha) when compared with the tributaries of other basins. The portion of the Kechery basin within the landscape has no native riparian forests, and its riparian zone is highly modified by human land uses.

6.2. Riparian forest types and classification of Anamalai landscape

The study carefully examines the riparian forest of the Anamalai landscape from several bioclimatic sampling zones and identified 11 primary cluster groups and 36 sub-clusters from the cluster analysis at different levels of the similarity coefficient. Using IVI, each cluster was assessed separately for dominating community relationships. The results allowed for the successful classification of the clusters, according to Bachan et al. (2022) and Bachan (2023), into three major types (T1.1. Rp. Tropical Moist Riparian Forest, T1.2. Rp. Tropical Dry Riparian Forest

(TDRp), and T1.3. Rp. Sub-Tropical Montane Riparian/ Streamside Forest (TStMRp) and twenty subtypes under the Tropical Subtropical Forest Biome. The maximum Shannon and Simpson diversity indices are found in Tropical Low-Elevation Evergreen riparian forests, whereas the lowest is in Secondary Moist Deciduous riparian forests. In the phytosociological analysis, 215 species of trees from 57 families and 146 genera were identified, which include 64 endemic species and 39 species of IUCN Red List categories (Near threatened – 6 Species, Vulnerable - 19 Species, Endangered - 12 Species, and Critically endangered (CR) *Garcinia imbertii* and *Diospyros crumenata*).

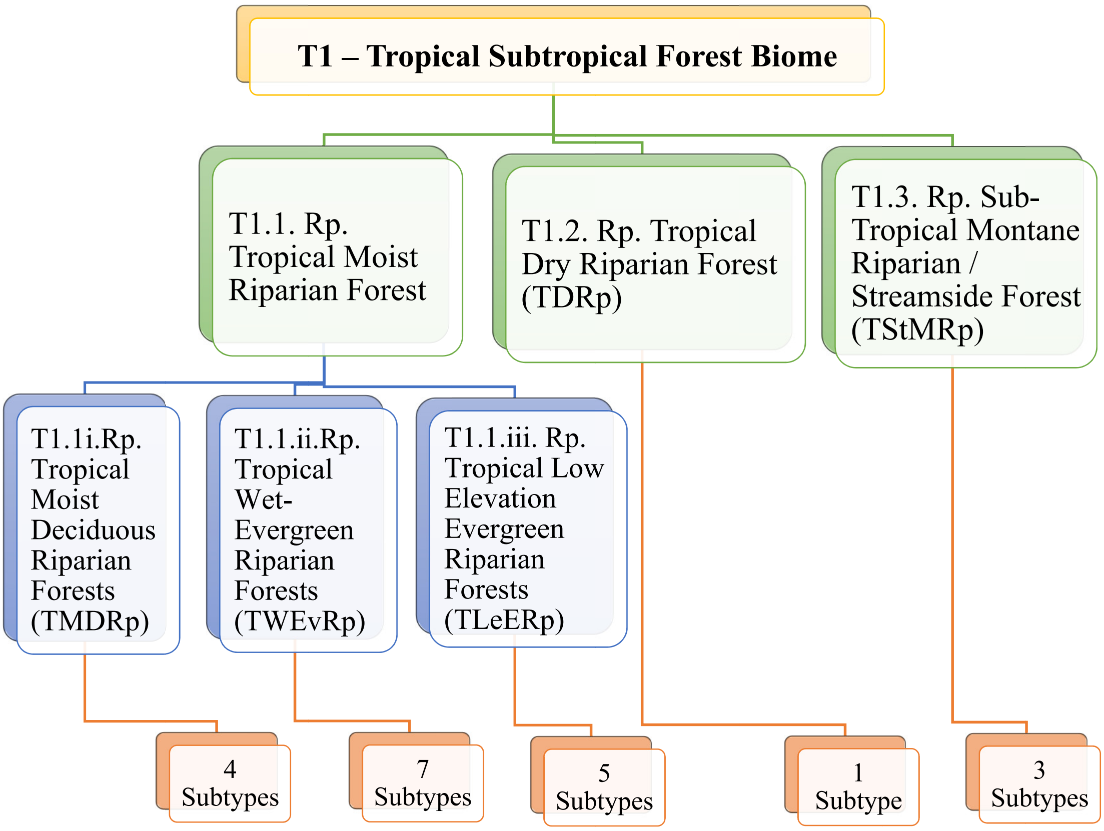

Fig. 6.3. Classification of riparian forest types and subtypes within the Anamalai landscape

During fieldwork and mapping, it became clear that the total area of riparian forest of the Anamalai landscape (697.06 ha) is declining and degrading (382.23 ha) due to anthropogenic activities, tourism, plantation, agricultural practices, pollution, and natural calamities. This caused erosion of riverbanks and if it persisted, that would seriously impact the vital ecosystem services provided by the riparian zones.

This study provides detailed input on the extent, composition and status of riparian forests along each river within the Anamalai landscape (Chalakudy, Periyar, Pambar, Bharathapuzha, Karuvannur and Kechery). It also highlights the importance of documentation of riparian forest cover of this unique, dynamic and endangered ecosystem. Hence, this study can act as baseline information for the riparian zone management of these rivers and contribute towards the identification of conservation and restoration areas of each river basin within the Anamalai landscape. This improves the riparian forest's regeneration and safeguards existing primary forest types. The detailed riparian compositions provided can be used for the identification of riparian forests in similar landscapes in future studies.

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RECOMMENDATIONS

The study mapped and described various bioclimatic zones in the Anamalai landscape, including the riparian forest cover. It also identified and classified different riparian vegetation types in the Anamalai landscape, considering the river basins as a subunit of the landscape. Based on the findings of the present study, the following recommendations are provided.

- The bioclimatic map of the Anamalai landscape provided in the present study can be used as a base data for delineating bioclimatic zones of other important landscapes of the Western Ghats.
- Meteorological data stations are recommended at each river basin and sub-basins, which can increase the accuracy of bioclimate delineation.
- Riparian zones should be continuous and dense to maximise and fulfil their ecological services.
- Reducing deforestation in riparian zones is the best solution for preventing biodiversity loss in aquatic and riparian ecosystems.
- The prepared riparian vegetation map of the Anamalai landscape can be used to prioritise riparian zones for conservation and restoration that can enhance the regeneration of riparian forests and, via that, the conservation of riparian-dependent species.
- These riparian vegetation maps can also be utilised for the identification of dense riparian zones for conservation and prioritising degraded riparian zones for ecorestoration.
- The most degraded Karuvannur, Kechery basins, Kuriyarkutty river, lower areas of Idamalayar, Pooyamkutty, and Aliyar rivers of the Anamalai landscape need immediate attention to restore degraded riparian forests.
- Existing plantations, agricultural fields, and degraded lands in the Chimmony, Mupli, Parambikulam, Kuriyarkutty, Kechery, Aliyar, Idamalayar, Pooyamkutty, and Chalakudy rivers riparian buffer zones require systematic replacement with characteristic riparian vegetation types.

- Any activities in the riparian zones need proper scientific assessments, especially restoration activities. Native riparian species based on the bioclimate need to be considered for planting.
- A continuous, unbroken riparian buffer zone of at least 30 metres in width should be maintained on both banks of higher-order rivers. Detailed studies are needed to standardise the buffer width needed to fulfil each river's ecological role, considering its order and flow. This should be included in the forest management plans and associated administrative departments.
- Every working plan for the forest department and panchayath level management plans or BMC must develop separate riparian management plans, considering the uniqueness of this vegetation type, and those plans must be implemented properly.
- Administrative authorities should constantly monitor and ensure the continuous flow of each river and its tributaries, especially in the dry season downstream to reservoirs, to ensure the survival of the riparian flora and fauna.
- Initiatives should be taken to educate people about the significance and services provided by the river and its riparian zone. Efforts to reorganise and monitor tourist ingress into the riparian zone are recommended to conduct tourism in a sustainable manner.
- Future studies are recommended to better understand the remaining river basins of the Western Ghats and India. Based on the bioclimate demarcation, mapping the extent of the riparian vegetation and identification of vegetation types that contribute to the elaboration of riparian vegetation classification.

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Appendices

APPENDIX – I

Locations of the meteorological stations of the Anamalai landscape

Sl. No.	Meteorological Station	Longitude	Latitude
1	Chinnakallar	76.964502	10.279649
2	Sarkarpatti	76.876684	10.474597
3	Vellanikkara	76.280000	10.530000
4	Munnar KSEB	77.070000	10.100000
5	Thrissur	76.220000	10.520000
6	Chalakudy	76.338051	10.307281
7	Poringalkuthu Dam	76.638458	10.313109
8	Chandramala Estate	76.696209	10.525759
9	Parambikulam Dam	76.794943	10.393519
10	Sholayar Dam	76.733197	10.315124
11	Perumbavoor	76.480000	10.120000
12	Irinjalakkuda	76.210000	10.340000
13	Kannara	76.340000	10.540000
14	Anamala	76.939866	10.264058
15	Sholayar Nagar	76.877920	10.298035
16	Valparai	76.956533	10.325093
17	Topslip	76.846126	10.470108
18	Lower Nirar Dam	76.933967	10.233716
19	Karappara Estate	76.641307	10.467808
20	Chinnar	77.219435	10.353008
21	Thellikkal	76.743638	10.453468
22	Aliyar Nagar	76.971285	10.488942

APPENDIX - II

Mean monthly rainfall, Temperature, & Number of dry months data collected from meteorological stations across the Anamalai Landscape

Sl. No	Meteorological station	Rainfall, Temperature & 2T	January	February	March	April	May	June	July	August	September	October	November	December	Temperature (Coldest month)
1	Thrissur	Rainfall (mm)	0.0	12.1	31.0	74.4	215.1	711.4	699.4	455.3	331.8	321.2	100.8	8.9	25.9
		T (^{0}C)	26.9	28.7	30.3	31.2	29.5	27.3	25.9	25.8	26.3	26.4	25.5	25.0	
		2T (^{0}C)	53.7	57.3	60.6	62.4	59.0	54.6	51.7	51.6	52.5	52.8	50.9	50.0	
2	Kannara	Rainfall (mm)	0.0	18.5	12.5	64.0	187.1	540.2	696.3	435.5	260.5	253.6	57.8	13.0	26.0
		T (^{0}C)	26.9	28.8	30.4	30.9	29.6	27.5	25.8	25.8	26.2	26.3	25.3	25.0	
		2T (^{0}C)	53.8	57.5	60.8	61.9	59.2	54.9	51.6	51.5	52.4	52.7	50.6	50.1	
3	Chalakudy	Rainfall (mm)	4.3	15.9	22.9	95.4	207.0	702.0	685.1	455.9	316.4	375.7	146.7	30.3	26.6
		T (^{0}C)	26.6	27.9	29.4	29.2	28.6	26.8	26.0	26.2	26.6	26.8	27.0	26.5	
		2T (^{0}C)	53.2	55.8	58.8	58.4	57.3	53.5	52.1	52.5	53.2	53.6	54.0	53.0	
4	Iringalakuda	Rainfall (mm)	4.2	10.2	15.2	48.9	229.8	685.1	592.8	390.1	357.1	330.8	117.4	16.8	26.1
		T (^{0}C)	26.9	28.7	30.4	31.2	29.6	27.3	25.9	25.9	26.3	26.5	25.6	25.2	
		2T (^{0}C)	53.8	57.4	60.7	62.3	59.2	54.6	51.8	51.7	52.6	53.0	51.2	50.4	
5	Vellanikkara	Rainfall (mm)	2.9	15.8	20.8	71.7	221.2	646.3	602.3	445.7	325.9	244.0	115.8	24.1	27.5
		T (^{0}C)	27.7	28.7	30.0	29.8	29.0	26.7	26.1	26.5	26.8	27.2	27.4	27.4	
		2T (^{0}C)	55.3	57.4	60.0	59.7	58.0	53.5	52.2	53.0	53.5	54.4	54.8	54.7	

6	Poringalkuthu	Rainfall (mm)	5.4	13.2	47.2	136.5	190.7	875.0	922.3	742.4	391.4	338.2	189.8	28.4	23.3
		T (^{0}C)	23.5	25.0	25.5	25.8	26.2	23.9	23.3	23.6	23.5	23.1	23.5	23.0	
		2T (^{0}C)	47.0	50.0	51.0	51.6	52.4	47.8	46.5	47.1	47.1	46.1	47.0	46.0	
7	Sholayar	Rainfall (mm)	11.1	16.6	46.2	125.4	197.0	954.4	994.0	897.4	408.6	321.1	185.0	26.8	19.4
		T (^{0}C)	19.8	23.0	23.2	24.6	25.1	20.0	20.3	21.0	21.2	22.0	22.1	19.0	
		2T (^{0}C)	39.6	46.0	46.4	49.2	50.2	40.0	40.6	42.0	42.4	44.0	44.2	38.0	
8	Chandramala	Rainfall (mm)	17.3	7.7	27.1	67.5	115.5	881.5	1063.1	973.7	221.6	196.9	117.2	30.8	22.8
		T (^{0}C)	23.2	25.3	27.8	29.8	29.0	24.8	23.4	23.5	23.8	24.0	22.3	22.4	
		2T (^{0}C)	46.4	50.7	55.6	59.5	57.9	49.7	46.7	47.0	47.6	48.0	44.7	44.8	
9	Karappara	Rainfall (mm)	1.5	2.2	25.5	94.7	169.1	844.1	1010.9	806.5	289.2	280.3	131.2	39.9	19.5
		T (^{0}C)	19.2	20.1	23.5	23.8	24.0	21.0	20.6	20.8	21.0	22.0	22.1	19.8	
		2T (^{0}C)	38.4	40.2	47.0	47.6	48.0	42.0	41.2	41.6	42.0	44.0	44.2	39.6	
10	Perumbavoor	Rainfall (mm)	11.8	21.8	43.9	143.7	238.0	637.6	676.4	432.1	418.0	310.7	227.4	50.8	26.8
		T (^{0}C)	27.3	28.8	30.2	30.4	28.9	27.4	26.2	26.1	26.5	26.9	26.7	26.3	
		2T (^{0}C)	54.5	57.5	60.5	60.9	57.9	54.8	52.4	52.2	53.0	53.8	53.4	52.6	
11	Munnar	Rainfall (mm)	5.7	13.6	61.6	132.7	197.3	705.5	921.3	682.3	415.3	319.2	135.9	37.6	21.0
		T (^{0}C)	21.4	23.7	25.8	27.6	26.6	23.8	22.5	22.6	23.2	23.1	21.7	20.6	
		2T (^{0}C)	42.8	47.4	51.6	55.2	53.3	47.5	45.1	45.3	46.5	46.2	43.4	41.1	
12	Lower Nirar Dam	Rainfall (mm)	23.5	19.1	36.3	86.3	214.4	837.0	958.6	737.1	339.4	319.2	176.2	42.7	20.9
		T (^{0}C)	21.3	23.7	26.0	28.0	26.9	23.7	22.1	22.4	23.0	23.1	21.8	20.6	
		2T (^{0}C)	42.5	47.3	52.0	55.9	53.8	47.4	44.2	44.8	46.1	46.1	43.5	41.2	

13	Parambikulam	Rainfall (mm)	5.7	4.8	26.8	104.3	139.6	355.6	402.4	274.5	115.2	152.6	47.7	32.7	21.1
		T (^{0}C)	20.9	22.7	25.6	25.2	24.5	23.9	23.3	23.6	23.5	23.1	22.1	21.3	
		2T (^{0}C)	41.8	45.4	51.2	50.3	49.0	47.8	46.5	47.1	46.9	46.1	44.2	42.6	
14	Chinnar	Rainfall (mm)	12.5	8.4	23.1	37.4	64.9	36.7	49.8	45.2	96.4	144.9	211.5	101.5	22.5
		T (^{0}C)	23.1	25.4	27.8	30.2	29.8	27.4	26.4	26.5	26.7	26.1	23.0	21.8	
		2T (^{0}C)	46.2	50.9	55.5	60.3	59.6	54.7	52.9	53.1	53.3	52.1	46.1	43.7	
15	Thellikkal	Rainfall (mm)	7.7	8.8	22.0	80.7	100.6	282.0	299.8	263.6	112.6	131.8	113.9	33.0	21.3
		T (^{0}C)	21.0	22.0	25.6	25.5	24.5	23.9	23.3	23.6	23.5	23.1	22.3	21.5	
		2T (^{0}C)	42.0	44.0	51.2	51.0	49.0	47.8	46.5	47.1	47.1	46.1	44.6	43.0	
16	Topslip	Rainfall (mm)	0.5	8.5	3.2	55.4	55.2	210.5	245.0	135.4	69.9	125.6	163.9	76.5	21.9
		T (^{0}C)	22.6	25.4	27.4	29.5	28.5	25.5	23.6	23.7	24.3	24.0	22.4	21.2	
		2T (^{0}C)	45.3	50.8	54.9	59.0	57.0	51.0	47.2	47.4	48.6	47.9	44.9	42.3	
17	Chinnakallore	Rainfall (mm)	7.0	12.9	25.0	88.7	149.4	838.2	1080.8	896.4	392.1	274.1	122.2	40.6	22.3
		T (^{0}C)	22.6	25.1	27.6	29.6	28.6	24.8	23.3	23.5	23.9	23.7	22.4	21.9	
		2T (^{0}C)	45.3	50.2	55.1	59.1	57.1	49.7	46.6	47.0	47.9	47.4	44.7	43.8	
18	Sholiyarnagar	Rainfall (mm)	10.5	8.6	30.9	137.8	194.3	818.7	1000.4	671.6	303.2	297.9	139.6	49.2	22.0
		T (^{0}C)	22.6	25.3	27.6	29.5	28.7	25.2	23.4	23.6	24.1	23.7	22.4	21.5	
		2T (^{0}C)	45.2	50.6	55.2	59.0	57.5	50.4	46.7	47.2	48.2	47.5	44.8	42.9	
19	Valparai	Rainfall (mm)	7.8	19.2	40.6	101.0	167.5	679.6	797.7	566.2	303.0	268.5	176.4	36.2	22.3
		T (^{0}C)	22.8	25.3	27.6	29.6	28.8	25.2	23.4	23.6	23.9	23.8	22.4	21.8	
		2T (^{0}C)	45.6	50.5	55.3	59.3	57.6	50.5	46.9	47.1	47.8	47.6	44.7	43.6	

20	Aliyar Nagar	Rainfall (mm)	12.2	10.6	20.5	58.7	70.2	74.0	94.8	67.1	46.6	152.4	129.7	40.9	22.3
		T (^{0}C)	22.9	25.4	27.6	29.6	28.7	25.2	23.5	23.6	24.1	24.0	22.4	21.8	
		2T (^{0}C)	45.8	50.8	55.2	59.3	57.4	50.4	47.0	47.2	48.1	48.0	44.8	43.5	
21	Anamala	Rainfall (mm)	6.8	12.8	40.6	108.7	149.0	719.1	926.6	712.3	349.4	295.0	155.8	29.6	22.1
		T (^{0}C)	22.6	25.2	27.6	29.5	28.6	25.2	23.4	23.6	23.9	23.7	22.4	21.6	
		2T (^{0}C)	45.2	50.3	55.2	59.1	57.2	50.3	46.7	47.1	47.8	47.4	44.8	43.2	
22	Sarkarpatti	Rainfall (mm)	5.5	9.3	17.0	43.4	88.2	177.0	153.4	108.4	91.1	155.9	83.5	19.3	22.2
		T (^{0}C)	22.8	25.3	27.6	29.6	28.3	25.3	23.6	23.8	24.2	24.2	22.3	21.5	
		2T (^{0}C)	45.6	50.6	55.2	59.2	56.6	50.5	47.2	47.6	48.5	48.4	44.6	43.0	

APPENDIX - III

Average & Mean probable year rainfall, Number of rainy days and Number of dry months for all meteorological stations of the Anamalai landscape

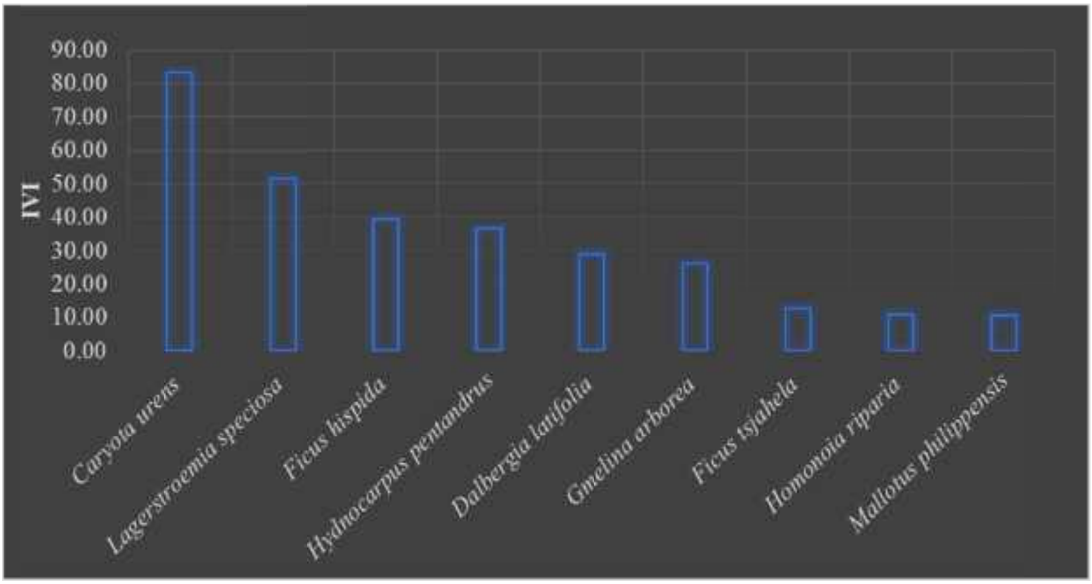
Sl. No	Meteorological station	Mean, SD, & Mean of probable year	Rainfall	Rainy days	No. of dry months
1	**Thrissur**	Mean	2961.328	108.389	4.778
		SD	717.035	16.912	0.732
		Mean of probable year	2950.200	111.308	4.769
2	**Kannara**	Mean	2538.710	108.700	4.900
		SD	530.700	8.407	0.738
		Mean of probable year	2393.600	107.667	4.889
3	**Chalakudy**	Mean	3057.670	121.690	4.615
		SD	571.481	11.810	0.941
		Mean of probable year	3082.683	121.720	4.556
4	**Iringalakuda**	Mean	2798.575	114.813	4.875
		SD	631.558	12.018	0.885
		Mean of probable year	2597.908	112.692	4.846
5	**Vellanikkara**	Mean	2736.427	114.182	4.545
		SD	537.230	10.907	1.128
		Mean of probable year	2758.929	116.714	4.571
6	**Poringalkuthu**	Mean	3880.586	133.000	3.600
		SD	809.744	20.034	1.188
		Mean of probable year	3852.000	133.000	3.000
7	**Sholayar**	Mean	4183.558	150.737	3.368
		SD	721.472	43.612	0.831
		Mean of probable year	4103.000	141.000	3.000
8	**Chandramala**	Mean	3719.900	131.500	4.333
		SD	712.873	23.177	1.155
		Mean of probable year	3823.544	127.556	4.222
9	**Karappara**	Mean	3694.920	136.400	3.550
		SD	956.988	19.755	0.999
		Mean of probable year	3716.162	138.385	3.615
10	**Perumbavoor**	Mean	3212.079	128.105	3.684
		SD	520.022	12.507	0.885
		Mean of probable year	3254.414	131.714	3.571
11	**Munnar**	Mean	3628.116	141.947	3.421
		SD	746.904	15.331	0.961
		Mean of probable year	3757.800	144.250	3.417
12	**Lower Nirar Dam**	Mean	3789.670	141.100	3.500

Sl. No	Meteorological station	Mean, SD, & Mean of probable year	Rainfall	Rainy days	No. of dry months
		SD	768.111	19.689	1.269
		Mean of probable year	3815.188	145.500	3.875
13	**Parambikulam**	Mean	1661.865	121.350	4.500
		SD	291.866	19.274	0.761
		Mean of probable year	1659.000	119.000	5.000
14	**Chinnar WLS**	Mean	832.260	50.000	6.800
		SD	190.461	0.000	0.680
		Mean of probable year	807.017	50.000	6.333
15	**Thellikkal**	Mean	1456.458	111.050	5.050
		SD	284.621	15.360	0.759
		Mean of probable year	1342.000	104.000	5.000
16	**Topslip**	Mean	1160.808	68.417	6.833
		SD	631.730	32.287	2.980
		Mean of probable year	1427.288	81.000	5.375
17	**Chinnakallore**	Mean	3927.168	131.105	4.263
		SD	686.247	16.176	0.991
		Mean of probable year	4088.300	133.714	4.286
18	**Sholiyarnagar**	Mean	3662.653	135.158	3.737
		SD	887.357	20.145	1.327
		Mean of probable year	3928.058	139.750	3.917
19	**Valparai**	Mean	3163.625	134.900	3.400
		SD	391.498	10.706	0.883
		Mean of probable year	3163.458	138.167	3.250
20	**Aliyar Nagar**	Mean	777.557	52.870	6.435
		SD	245.111	12.800	1.647
		Mean of probable year	730.231	52.813	6.500
21	**Anamala**	Mean	3505.727	135.773	4.227
		SD	696.725	18.066	1.110
		Mean of probable year	3610.240	138.000	4.200
22	**Sarkarpatti**	Mean	1445.508	72.857	5.630
		SD	229.164	22.295	0.967
		Mean of probable year	1402.404	76.750	5.813

APPENDIX - IV

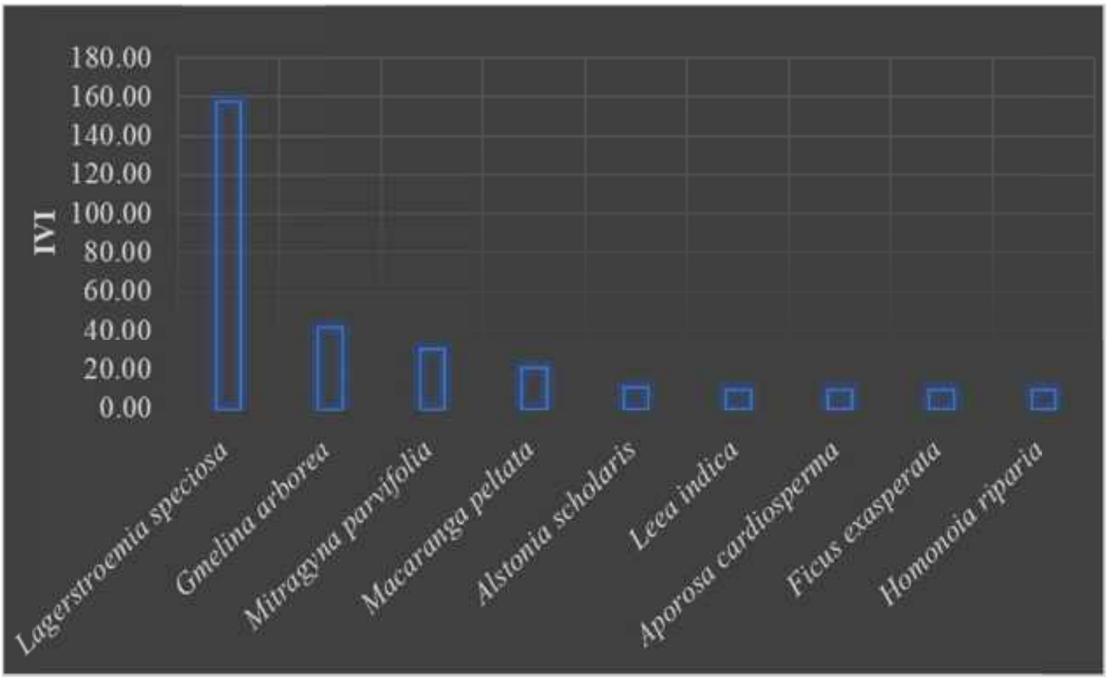
Phytosociological data for the identified clusters of the Anamalai landscape

1. Dominant species associations in Cluster 1a



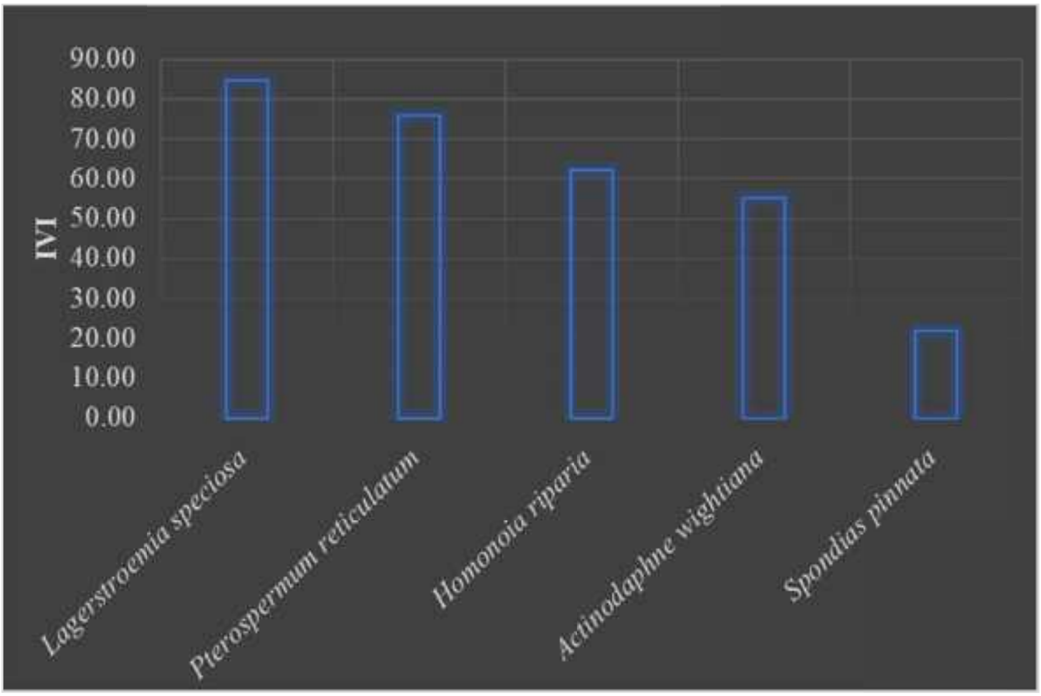
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Caryota urens*	1	1	0.54	20	20	43.42	83.42
2	*Lagerstroemia speciosa*	1	1	0.15	20	20	11.7	51.7
3	*Ficus hispida*	0.75	0.75	0.11	15	15	9.25	39.25
4	*Hydnocarpus pentandrus*	0.5	0.5	0.2	10	10	16.44	36.44
5	*Dalbergia latifolia*	0.5	0.5	0.11	10	10	8.94	28.94
6	*Gmelina arborea*	0.5	0.5	0.08	10	10	6.17	26.17
7	*Ficus tsjahela*	0.25	0.25	0.03	5	5	2.71	12.71
8	*Homonoia riparia*	0.25	0.25	0.01	5	5	0.79	10.79
9	*Mallotus philippensis*	0.25	0.25	0.01	5	5	0.58	10.58
Total		5	5	1.24	100	100	100	300

2. **Dominant species associations in Cluster - 1b**



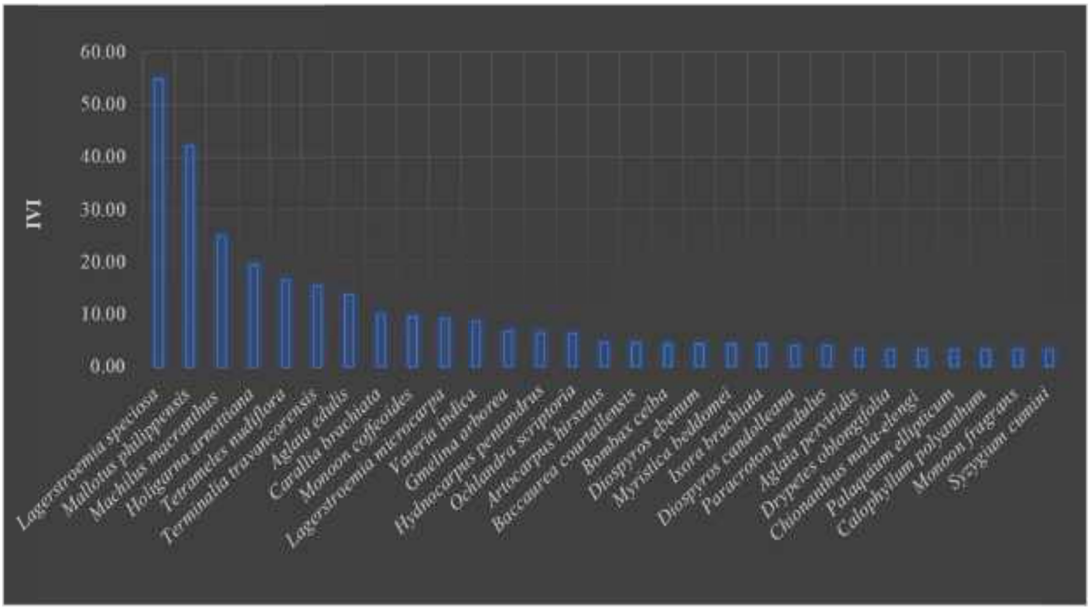
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Lagerstroemia speciosa*	1.71	1	2.38	48	36.84	73.08	157.92
2	*Gmelina arborea*	0.57	0.43	0.34	16	15.79	10.36	42.15
3	*Mitragyna parvifolia*	0.29	0.29	0.39	8	10.53	12.04	30.56
4	*Macaranga peltata*	0.29	0.29	0.07	8	10.53	2.16	20.68
5	*Alstonia scholaris*	0.14	0.14	0.04	4	5.26	1.37	10.64
6	*Leea indica*	0.14	0.14	0.01	4	5.26	0.3	9.56
7	*Aporosa cardiosperma*	0.14	0.14	0.01	4	5.26	0.25	9.51
8	*Ficus exasperata*	0.14	0.14	0.01	4	5.26	0.22	9.48
9	*Homonoia riparia*	0.14	0.14	0.01	4	5.26	0.22	9.48
Total		3.57	2.71	3.26	100	100	100	300

3. Dominant species associations in Cluster - 1c



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Lagerstroemia speciosa*	1	1.5	0.11	23.08	28.13	33.58	84.78
2	*Pterospermum reticulatum*	1	1	0.11	23.08	18.75	34.14	75.97
3	*Homonoia riparia*	1	1.5	0.04	23.08	28.13	10.96	62.17
4	*Actinodaphne wightiana*	1	1	0.04	23.08	18.75	13.34	55.16
5	*Spondias pinnata*	0.33	0.33	0.03	7.69	6.25	7.98	21.92
Total		4.33	5.33	0.34	100	100	100	300

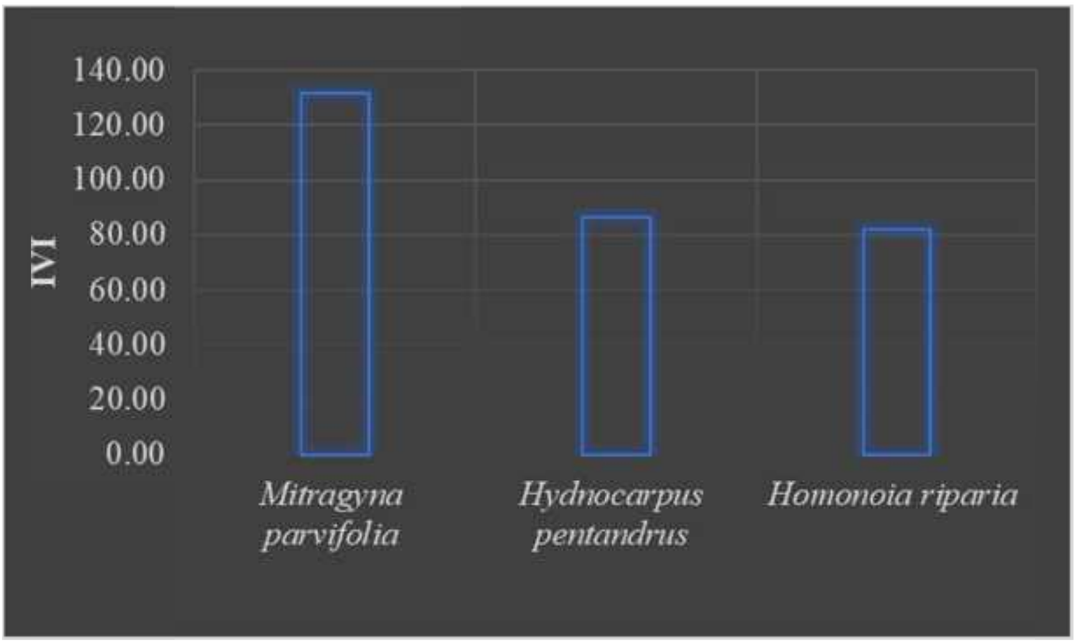
4. Dominant species associations in Cluster - 1d



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Lagerstroemia speciosa*	3.25	1	10.6	13.54	8.33	32.89	54.77
2	*Mallotus philippensis*	6	0.5	4.21	25	4.17	13.01	42.18
3	*Machilus macranthus*	1.25	0.75	4.36	5.21	6.25	13.48	24.94
4	*Holigarna arnottiana*	1.25	1	1.91	5.21	8.33	5.91	19.45
5	*Tetrameles nudiflora*	1	1	1.33	4.17	8.33	4.1	16.6
6	*Terminalia travancorensis*	0.5	0.25	3.63	2.08	2.08	11.21	15.38
7	*Aglaia edulis*	1	0.5	1.76	4.17	4.17	5.44	13.77
8	*Carallia brachiata*	1	0.5	0.54	4.17	4.17	1.66	10
9	*Monoon coffeoides*	1.25	0.25	0.7	5.21	2.08	2.16	9.45
10	*Lagerstroemia microcarpa*	0.75	0.5	0.6	3.13	4.17	1.86	9.15
11	*Vateria indica*	1	0.5	0.06	4.17	4.17	0.18	8.51
12	*Gmelina arborea*	0.5	0.5	0.13	2.08	4.17	0.42	6.67
13	*Hydnocarpus pentandrus*	0.5	0.5	0.03	2.08	4.17	0.09	6.34
14	*Ochlandra scriptoria*	0.5	0.5	0.01	2.08	4.17	0.02	6.27
15	*Artocarpus hirsutus*	0.25	0.25	0.46	1.04	2.08	1.42	4.54
16	*Baccaurea courtallensis*	0.5	0.25	0.06	2.08	2.08	0.2	4.37

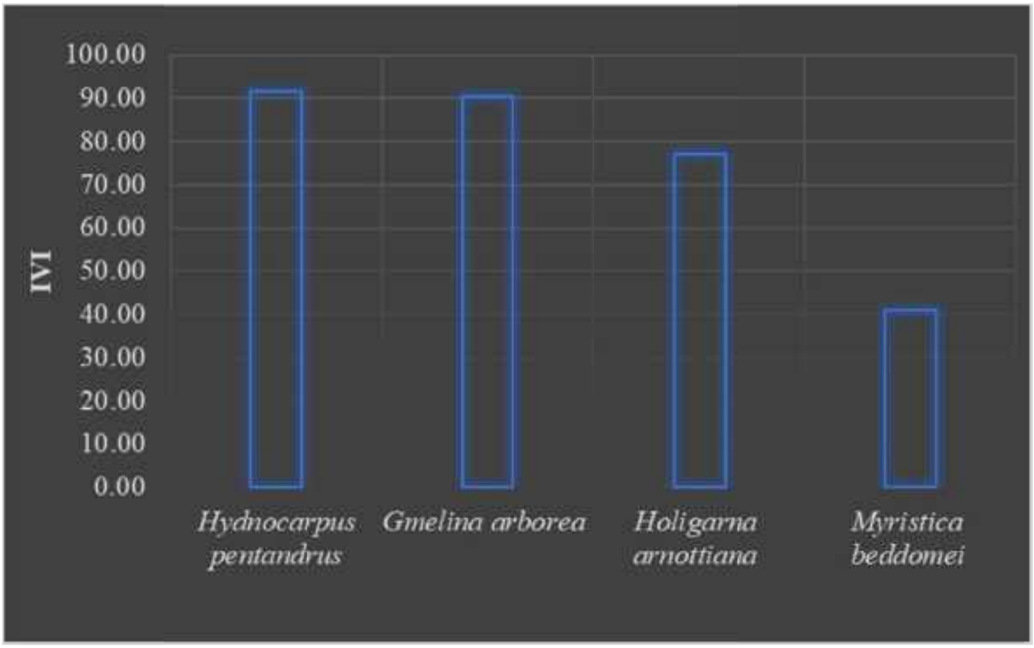
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
17	*Bombax ceiba*	0.25	0.25	0.39	1.04	2.08	1.19	4.32
18	*Diospyros ebenum*	0.25	0.25	0.39	1.04	2.08	1.19	4.32
19	*Myristica beddomei*	0.25	0.25	0.39	1.04	2.08	1.19	4.32
20	*Ixora brachiata*	0.5	0.25	0.03	2.08	2.08	0.1	4.27
21	*Diospyros candolleana*	0.25	0.25	0.29	1.04	2.08	0.89	4.01
22	*Paracroton pendulus*	0.25	0.25	0.25	1.04	2.08	0.78	3.9
23	*Aglaia perviridis*	0.25	0.25	0.09	1.04	2.08	0.27	3.4
24	*Drypetes oblongifolia*	0.25	0.25	0.03	1.04	2.08	0.09	3.22
25	*Chionanthus mala-elengi*	0.25	0.25	0.03	1.04	2.08	0.09	3.21
26	*Palaquium ellipticum*	0.25	0.25	0.02	1.04	2.08	0.06	3.19
27	*Calophyllum polyanthum*	0.25	0.25	0.01	1.04	2.08	0.04	3.16
28	*Monoon fragrans*	0.25	0.25	0.01	1.04	2.08	0.03	3.16
29	*Syzygium cumini*	0.25	0.25	0.01	1.04	2.08	0.03	3.16
Total		24	12	32.35	100	100	100	300

5. Dominant species associations in Cluster - 2a



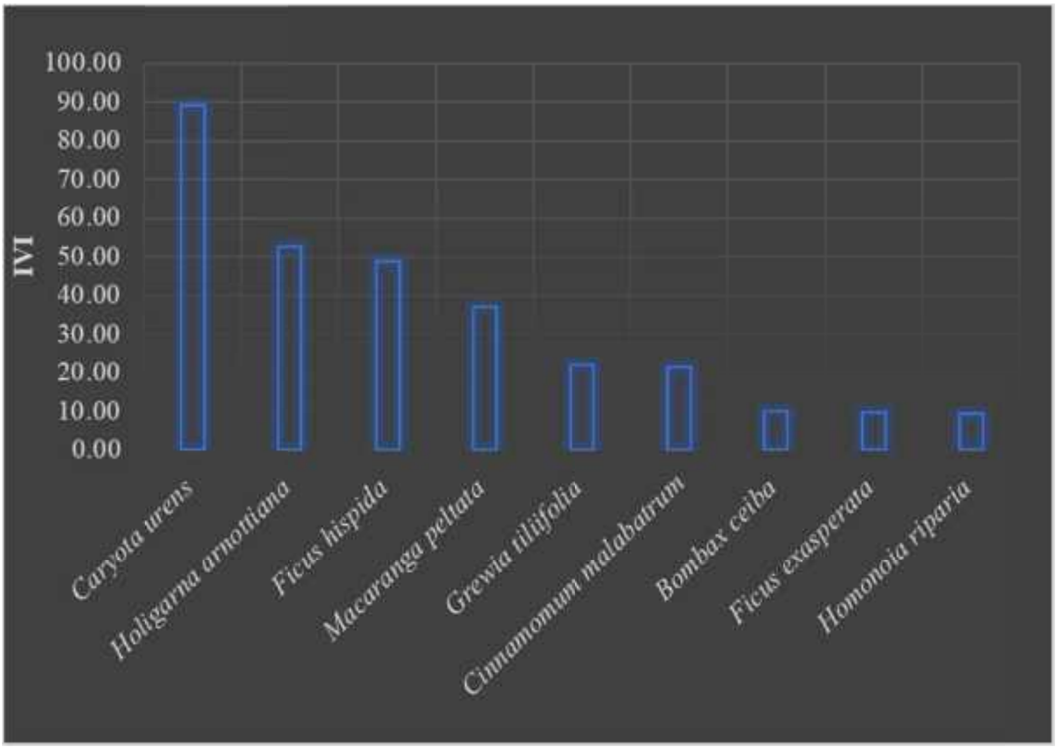
Sl No.	Name of Species	D	F	RD	RF	RBA	IVI
1	*Mitragyna parvifolia*	1.33	0.67	40	33.33	58.27	131.6
2	*Hydnocarpus pentandrus*	0.67	0.67	20	33.33	33.11	86.45
3	*Homonoia riparia*	1.33	0.67	40	33.33	8.62	81.95
Total		3.33	2	100	100	100	300

6. Dominant species associations in Cluster - 2b



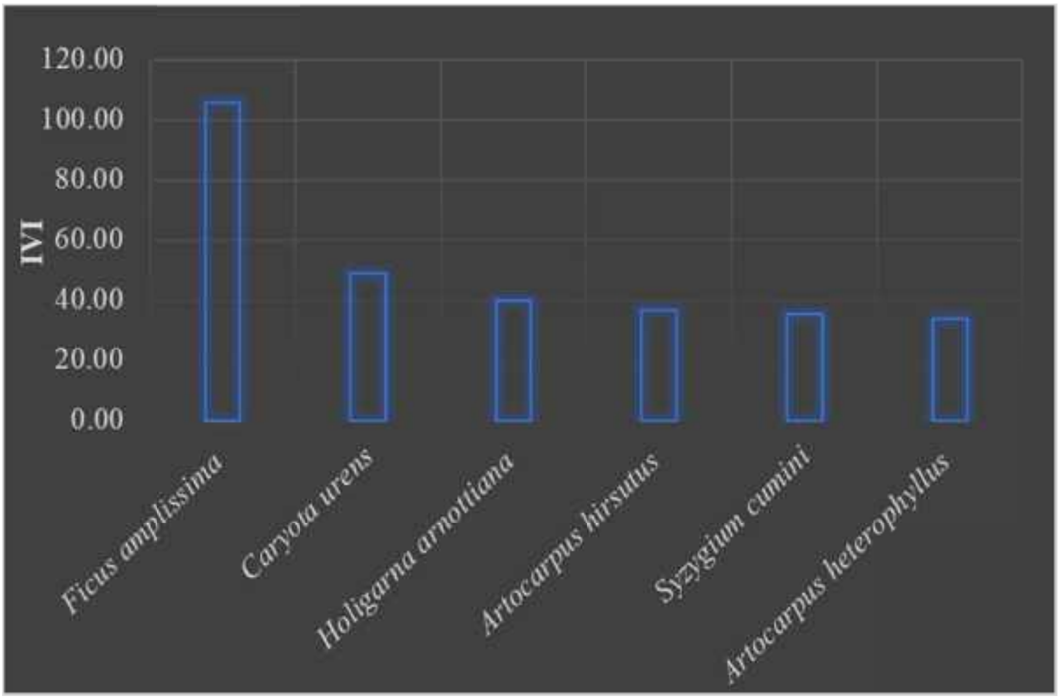
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Hydnocarpus pentandrus*	1.33	1.67	0.61	30.77	27.78	33.12	91.67
2	*Gmelina arborea*	1	2	0.62	23.08	33.33	34.09	90.5
3	*Holigarna arnottiana*	1	1.33	0.58	23.08	22.22	31.7	77
4	*Myristica beddomei*	1	1	0.02	23.08	16.67	1.09	40.83
Total		4.33	6.00	1.83	100	100	100	300

7. Dominant species associations in Cluster - 3a



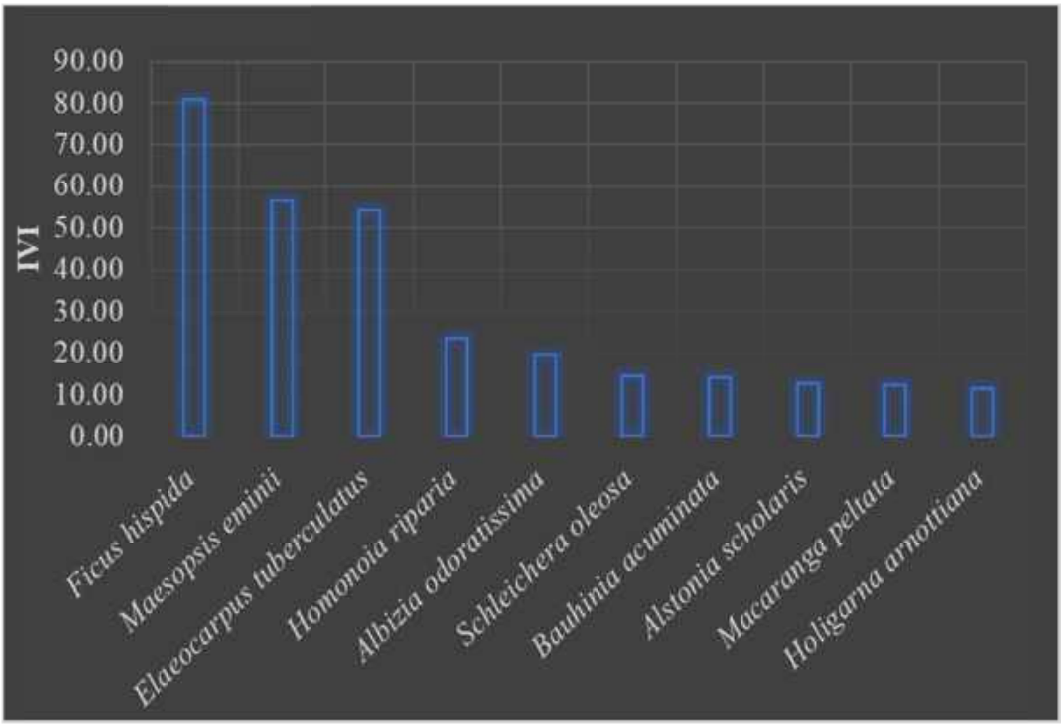
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Caryota urens*	1.75	1	0.48	28	19.05	42.16	89.21
2	*Holigarna arnottiana*	1	1	0.2	16	19.05	17.54	52.58
3	*Ficus hispida*	1	0.75	0.21	16	14.29	18.44	48.72
4	*Macaranga peltata*	0.75	0.75	0.12	12	14.29	10.8	37.09
5	*Grewia tiliifolia*	0.5	0.5	0.05	8	9.52	4.5	22.02
6	*Cinnamomum malabatrum*	0.5	0.5	0.04	8	9.52	3.95	21.48
7	*Bombax ceiba*	0.25	0.25	0.01	4	4.76	1.12	9.89
8	*Ficus exasperata*	0.25	0.25	0.01	4	4.76	0.86	9.62
9	*Homonoia riparia*	0.25	0.25	0.01	4	4.76	0.63	9.39
Total		6.25	5.25	1.13	100	100	100	300

8. Dominant species associations in Cluster - 3b



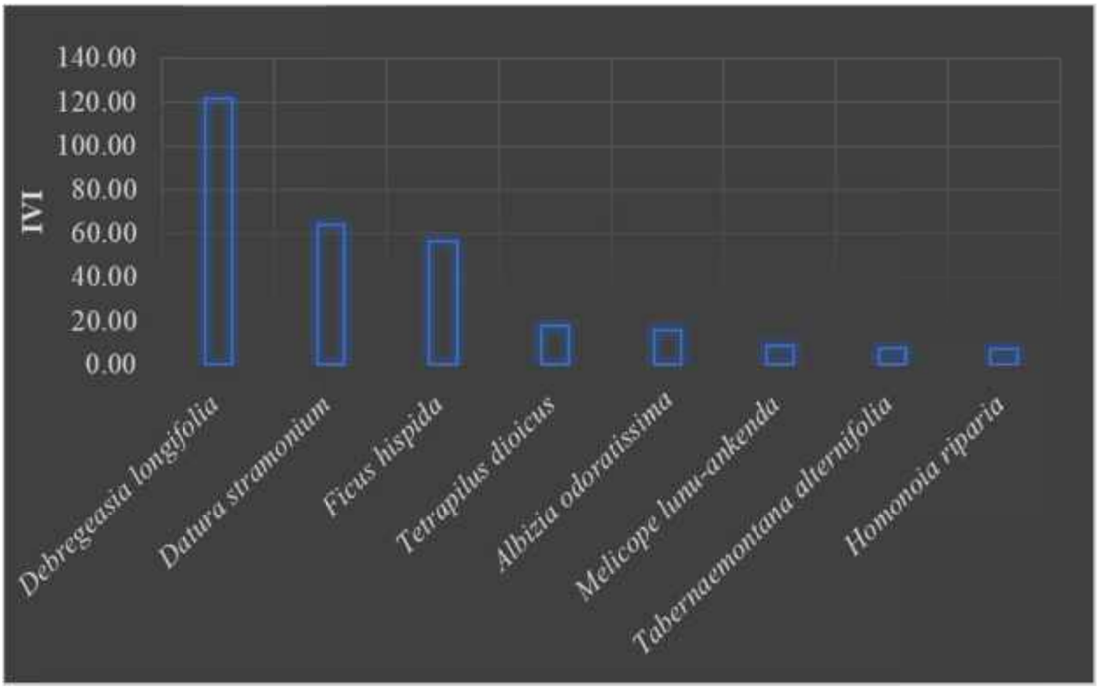
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Ficus amplissima*	1	1	1.15	12.5	20	73.2	105.7
2	*Caryota urens*	2	1	0.06	25	20	3.66	48.66
3	*Holigarna arnottiana*	1	1	0.11	12.5	20	7.3	39.8
4	*Artocarpus hirsutus*	1.5	0.5	0.12	18.75	10	7.92	36.67
5	*Syzygium cumini*	1	1	0.04	12.5	20	2.85	35.35
6	Artocarpus heterophyllus	1.5	0.5	0.08	18.75	10	5.07	33.82
Total		8.00	5.00	1.57	100	100	100	300

9. Dominant species associations in Cluster – 4a



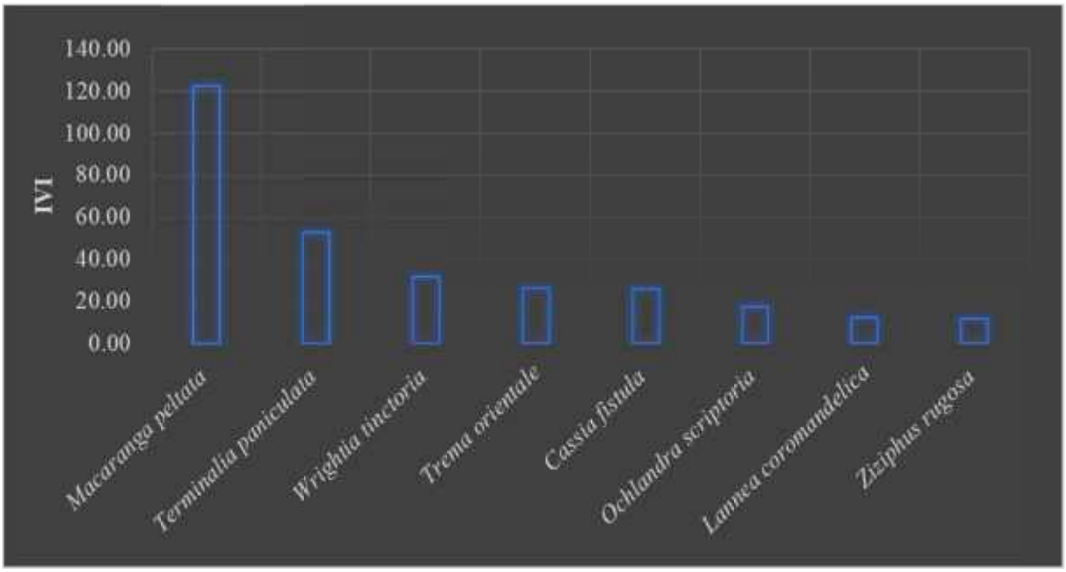
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Ficus hispida*	2	1	0.3	36.36	25	19.63	80.99
2	*Maesopsis eminii*	0.75	0.5	0.47	13.64	12.5	30.48	56.62
3	*Elaeocarpus tuberculatus*	0.5	0.5	0.51	9.09	12.5	32.78	54.38
4	*Homonoia riparia*	0.5	0.5	0.03	9.09	12.5	1.92	23.51
5	*Albizia odoratissima*	0.5	0.25	0.06	9.09	6.25	4.09	19.43
6	*Schleichera oleosa*	0.25	0.25	0.06	4.55	6.25	3.73	14.53
7	*Bauhinia acuminata*	0.25	0.25	0.05	4.55	6.25	3.3	14.1
8	*Alstonia scholaris*	0.25	0.25	0.03	4.55	6.25	1.86	12.65
9	*Macaranga peltata*	0.25	0.25	0.02	4.55	6.25	1.56	12.36
10	*Holigarna arnottiana*	0.25	0.25	0.01	4.55	6.25	0.63	11.43
Total		5.5	4	1.54	100	100	100	300

10. Dominant species associations in Cluster - 4b



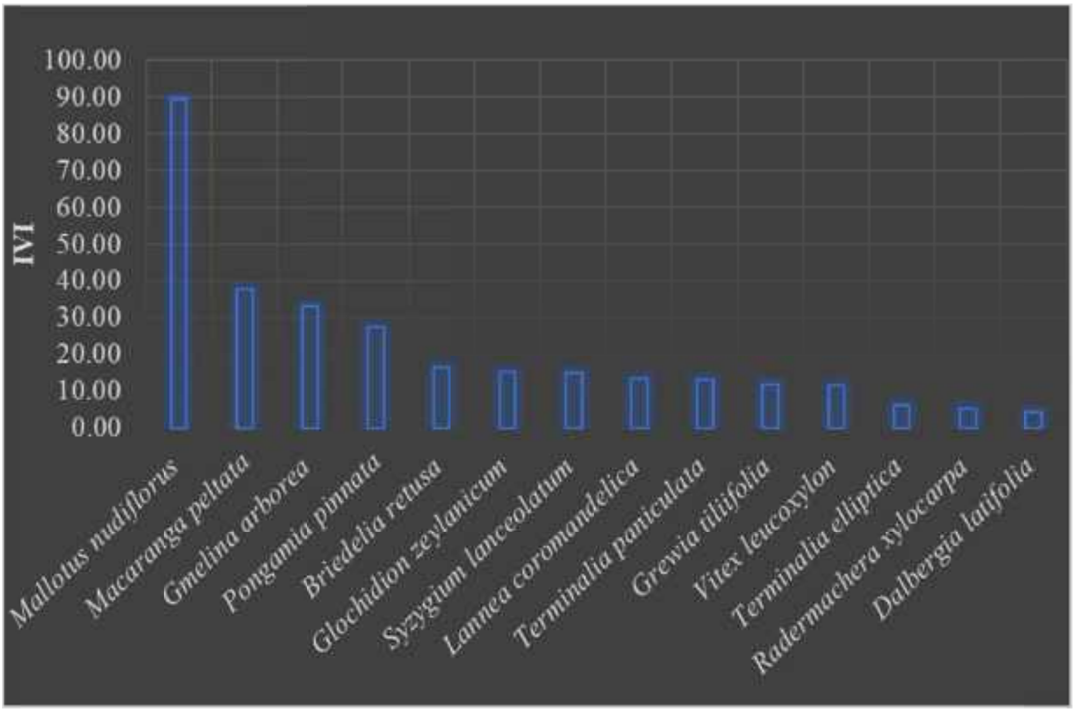
Sl No.	Name of Species	D	F	BA (m2)	RD	RF	RBA	IVI
1	*Debregeasia longifolia*	1.86	1.00	1.13	28.26	33.33	60.11	121.70
2	*Datura stramonium*	2.43	0.57	0.15	36.96	19.05	8.17	64.18
3	*Ficus hispida*	1.29	0.71	0.24	19.57	23.81	12.95	56.33
4	*Tetrapilus dioicus*	0.43	0.14	0.13	6.52	4.76	6.71	18.00
5	*Albizia odoratissima*	0.14	0.14	0.17	2.17	4.76	8.77	15.71
6	*Melicope lunu-ankenda*	0.14	0.14	0.04	2.17	4.76	1.96	8.89
7	*Tabernaemontana alternifolia*	0.14	0.14	0.02	2.17	4.76	0.89	7.83
8	*Homonoia riparia*	0.14	0.14	0.01	2.17	4.76	0.43	7.37
Total		6.57	3	1.88	100	100	100	300

11. Dominant species associations in Cluster - 5a



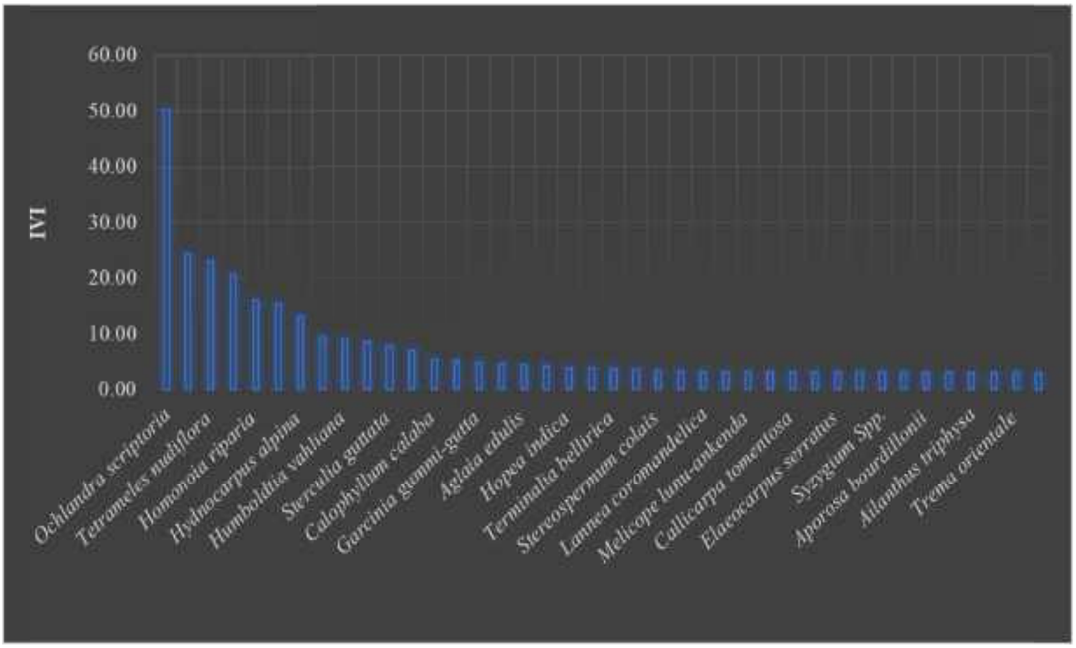
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Macaranga peltata*	1.75	1	0.95	35	26.67	60.83	122.5
2	*Terminalia paniculata*	0.5	0.5	0.46	10	13.33	29.68	53.02
3	*Wrightia tinctoria*	0.75	0.5	0.05	15	13.33	3.27	31.6
4	*Trema orientale*	0.5	0.5	0.04	10	13.33	2.72	26.06
5	*Cassia fistula*	0.5	0.5	0.04	10	13.33	2.36	25.7
6	*Ochlandra scriptoria*	0.5	0.25	0.01	10	6.67	0.46	17.13
7	*Lannea coromandelica*	0.25	0.25	0.01	5	6.67	0.4	12.07
8	*Ziziphus rugosa*	0.25	0.25	0.01	5	6.67	0.27	11.94
Total		5	3.75	1.55	100	100	100	300

12. Dominant species associations in Cluster - 5b



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Mallotus nudiflorus*	3.14	1	9.29	29.73	15.22	44.43	89.39
2	*Macaranga peltata*	1	0.86	3.22	9.46	13.05	15.41	37.92
3	*Gmelina arborea*	1	0.71	2.67	9.46	10.87	12.77	33.1
4	*Pongamia pinnata*	1	0.71	1.46	9.46	10.87	6.98	27.31
5	*Briedelia retusa*	0.57	0.57	0.5	5.41	8.7	2.38	16.48
6	*Glochidion zeylanicum var. zeylanicum*	0.57	0.57	0.27	5.41	8.7	1.28	15.38
7	*Syzygium lanceolatum*	0.43	0.43	0.9	4.05	6.52	4.3	14.88
8	*Lannea coromandelica*	0.57	0.29	0.77	5.41	4.35	3.68	13.44
9	*Terminalia paniculata*	0.43	0.29	1	4.05	4.35	4.77	13.18
10	*Grewia tiliifolia*	0.43	0.43	0.25	4.05	6.52	1.21	11.78
11	*Vitex leucoxylon*	0.71	0.29	0.1	6.76	4.35	0.49	11.59
12	*Terminalia elliptica*	0.29	0.14	0.28	2.7	2.17	1.33	6.21
13	*Radermachera xylocarpa*	0.29	0.14	0.06	2.7	2.17	0.3	5.17
14	*Dalbergia latifolia*	0.14	0.14	0.17	1.35	2.17	0.79	4.32
Total		10.57	6.57	20.92	100	100	100	300

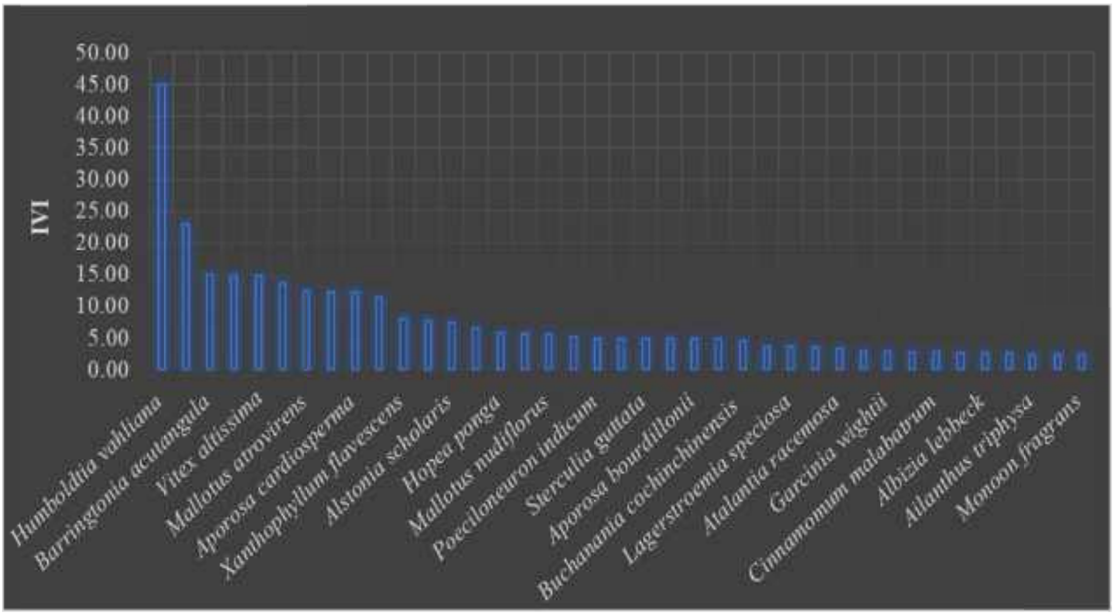
13. Dominant species associations in Cluster - 6a



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Ochlandra scriptoria*	4.2	1	2.49	23.08	8.62	18.49	50.19
2	*Ochlandra travancorica*	0.8	0.4	2.21	4.4	3.45	16.43	24.28
3	*Tetrameles nudiflora*	0.8	0.6	1.82	4.4	5.17	13.52	23.09
4	*Macaranga peltata*	1.2	0.8	0.96	6.59	6.9	7.13	20.62
5	*Homonoia riparia*	1.4	0.6	0.43	7.69	5.17	3.18	16.05
6	*Mangifera indica*	0.4	0.2	1.54	2.2	1.72	11.46	15.38
7	*Hydnocarpus alpina*	0.8	0.4	0.7	4.4	3.45	5.22	13.06
8	*Terminalia paniculata*	0.4	0.4	0.48	2.2	3.45	3.58	9.23
9	*Humboldtia vahliana*	0.6	0.4	0.28	3.3	3.45	2.07	8.81
10	*Antidesma montanum*	0.6	0.4	0.22	3.3	3.45	1.65	8.4
11	*Sterculia guttata*	0.4	0.4	0.28	2.2	3.45	2.05	7.69
12	*Ziziphus rugosa*	0.6	0.4	0.02	3.3	3.45	0.14	6.89
13	*Calophyllum calaba*	0.2	0.2	0.32	1.1	1.72	2.37	5.19
14	*Schleichera oleosa*	0.2	0.2	0.3	1.1	1.72	2.25	5.07
15	*Garcinia gummi-gutta*	0.4	0.2	0.11	2.2	1.72	0.78	4.7
16	*Holoptelea integrifolia*	0.4	0.2	0.07	2.2	1.72	0.51	4.43
17	*Aglaia edulis*	0.2	0.2	0.2	1.1	1.72	1.46	4.28
18	*Syzygium mundagam*	0.2	0.2	0.17	1.1	1.72	1.24	4.07
19	*Hopea indica*	0.2	0.2	0.13	1.1	1.72	1	3.82
20	*Hydnocarpus pentandrus*	0.2	0.2	0.13	1.1	1.72	1	3.82
21	*Terminalia bellirica*	0.2	0.2	0.11	1.1	1.72	0.8	3.62
22	*Myristica malabarica*	0.2	0.2	0.09	1.1	1.72	0.65	3.48

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
23	*Stereospermum colais*	0.2	0.2	0.05	1.1	1.72	0.38	3.2
24	*Tectona grandis*	0.2	0.2	0.04	1.1	1.72	0.31	3.13
25	*Lannea coromandelica*	0.2	0.2	0.04	1.1	1.72	0.27	3.1
26	*Alstonia scholaris*	0.2	0.2	0.03	1.1	1.72	0.25	3.07
27	*Melicope lunu-ankenda*	0.2	0.2	0.03	1.1	1.72	0.23	3.05
28	*Vitex altissima*	0.2	0.2	0.02	1.1	1.72	0.19	3.01
29	*Callicarpa tomentosa*	0.2	0.2	0.02	1.1	1.72	0.18	3
30	*Cinnamomum riparium*	0.2	0.2	0.02	1.1	1.72	0.17	2.99
31	*Elaeocarpus serratus*	0.2	0.2	0.02	1.1	1.72	0.16	2.98
32	*Aporosa cardiosperma*	0.2	0.2	0.02	1.1	1.72	0.14	2.96
33	*Syzygium Spp.*	0.2	0.2	0.02	1.1	1.72	0.14	2.96
34	*Cassia fistula*	0.2	0.2	0.02	1.1	1.72	0.12	2.94
35	*Aporosa bourdillonii*	0.2	0.2	0.01	1.1	1.72	0.1	2.93
36	*Briedelia retusa*	0.2	0.2	0.01	1.1	1.72	0.1	2.93
37	*Ailanthus triphysa*	0.2	0.2	0.01	1.1	1.72	0.09	2.91
38	*Bombax ceiba*	0.2	0.2	0.01	1.1	1.72	0.07	2.89
39	*Trema orientale*	0.2	0.2	0.01	1.1	1.72	0.07	2.89
40	*Capparis baducca*	0.2	0.2	0.01	1.1	1.72	0.06	2.88
Total		18.2	11.6	13.45	100	100	100	300

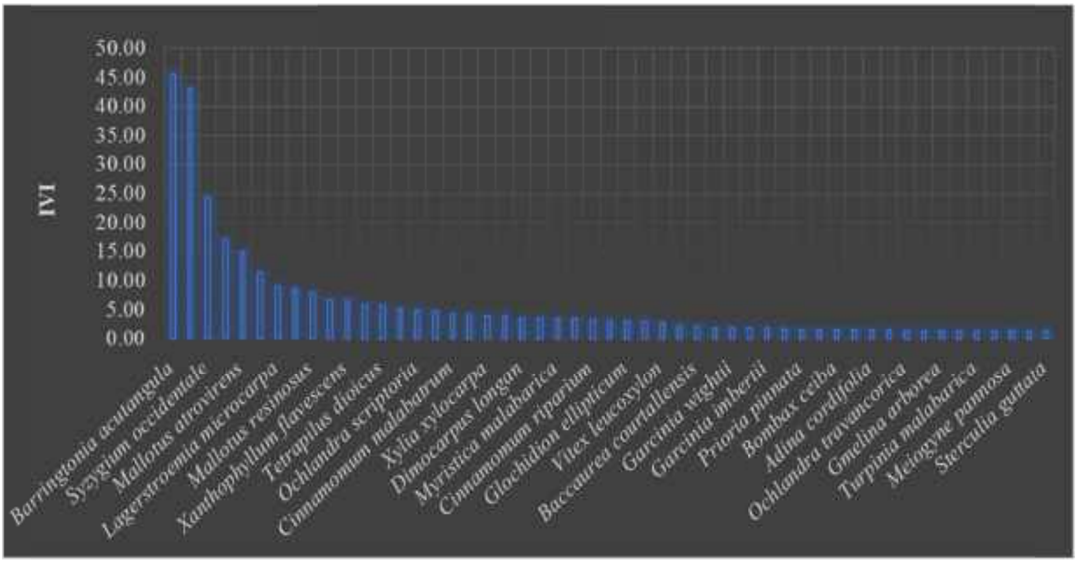
14. Dominant species associations in Cluster - 6b



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Humboldtia vahliana*	4.25	1	7.87	14.78	5.97	24.35	45.11
2	*Schleichera oleosa*	1.25	1	4.1	4.35	5.97	12.71	23.02
3	*Barringtonia acutangula*	2	0.75	1.15	6.96	4.48	3.56	14.99
4	*Holigarna arnottiana*	1.5	0.75	1.65	5.22	4.48	5.1	14.8
5	*Vitex altissima*	1.25	0.75	1.92	4.35	4.48	5.94	14.77
6	*Leea indica*	1.75	1	0.52	6.09	5.97	1.62	13.67
7	*Mallotus atrovirens*	1.75	0.25	1.57	6.09	1.49	4.86	12.44
8	*Lagerstroemia microcarpa*	0.75	0.25	2.64	2.61	1.49	8.18	12.28
9	*Aporosa cardiosperma*	1.5	1	0.33	5.22	5.97	1.04	12.22
10	*Ochlandra scriptoria*	1	0.5	1.57	3.48	2.99	4.86	11.32
11	*Xanthophyllum flavescens*	0.75	0.5	0.79	2.61	2.99	2.45	8.04
12	*Diospyros crumenata*	0.75	0.25	1.15	2.61	1.49	3.56	7.66
13	*Alstonia scholaris*	0.5	0.5	0.88	1.74	2.99	2.72	7.44
14	*Garcinia gummi-gutta*	0.5	0.5	0.56	1.74	2.99	1.73	6.46
15	*Hopea ponga*	0.5	0.5	0.33	1.74	2.99	1.04	5.76
16	*Tetrapilus dioicus*	0.5	0.5	0.26	1.74	2.99	0.82	5.54
17	*Mallotus nudiflorus*	0.5	0.5	0.26	1.74	2.99	0.8	5.52
18	*Hydnocarpus alpina*	0.5	0.25	0.62	1.74	1.49	1.93	5.16
19	*Poeciloneuron indicum*	0.25	0.25	0.82	0.87	1.49	2.52	4.89
20	*Vateria indica*	0.25	0.25	0.82	0.87	1.49	2.52	4.89
21	*Sterculia guttata*	0.75	0.25	0.23	2.61	1.49	0.72	4.82
22	*Garcinia cambogioides var. cambogioides*	0.5	0.5	0.03	1.74	2.99	0.09	4.82
23	*Aporosa bourdillonii*	0.5	0.5	0.03	1.74	2.99	0.09	4.81
24	*Capparis baducca*	0.5	0.5	0.02	1.74	2.99	0.06	4.79
25	*Buchanania cochinchinen sis*	0.25	0.25	0.69	0.87	1.49	2.15	4.51
26	*Gmelina arborea*	0.5	0.25	0.16	1.74	1.49	0.48	3.71
27	*Lagerstroemia speciosa*	0.25	0.25	0.41	0.87	1.49	1.26	3.62
28	*Hopea indica*	0.5	0.25	0.07	1.74	1.49	0.23	3.46
29	*Atalantia racemosa*	0.5	0.25	0.02	1.74	1.49	0.06	3.29
30	*Glochidion zeylanicum*	0.25	0.25	0.19	0.87	1.49	0.59	2.95

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
	var. zeylanicum							
31	*Garcinia wightii*	0.25	0.25	0.18	0.87	1.49	0.55	2.92
32	*Flacourtia montana*	0.25	0.25	0.11	0.87	1.49	0.35	2.72
33	*Cinnamomum malabatrum*	0.25	0.25	0.11	0.87	1.49	0.33	2.69
34	*Myristica malabarica*	0.25	0.25	0.09	0.87	1.49	0.27	2.63
35	*Albizia lebbeck*	0.25	0.25	0.07	0.87	1.49	0.23	2.59
36	*Madhuca neriifolia*	0.25	0.25	0.05	0.87	1.49	0.16	2.52
37	*Ailanthus triphysa*	0.25	0.25	0.01	0.87	1.49	0.03	2.39
38	*Diospyros buxifolia*	0.25	0.25	0.01	0.87	1.49	0.03	2.39
39	*Monoon fragrans*	0.25	0.25	0.01	0.87	1.49	0.02	2.38
Total		28.75	16.75	32.30	100	100	100	300

15. Dominant species associations in Cluster – 6c

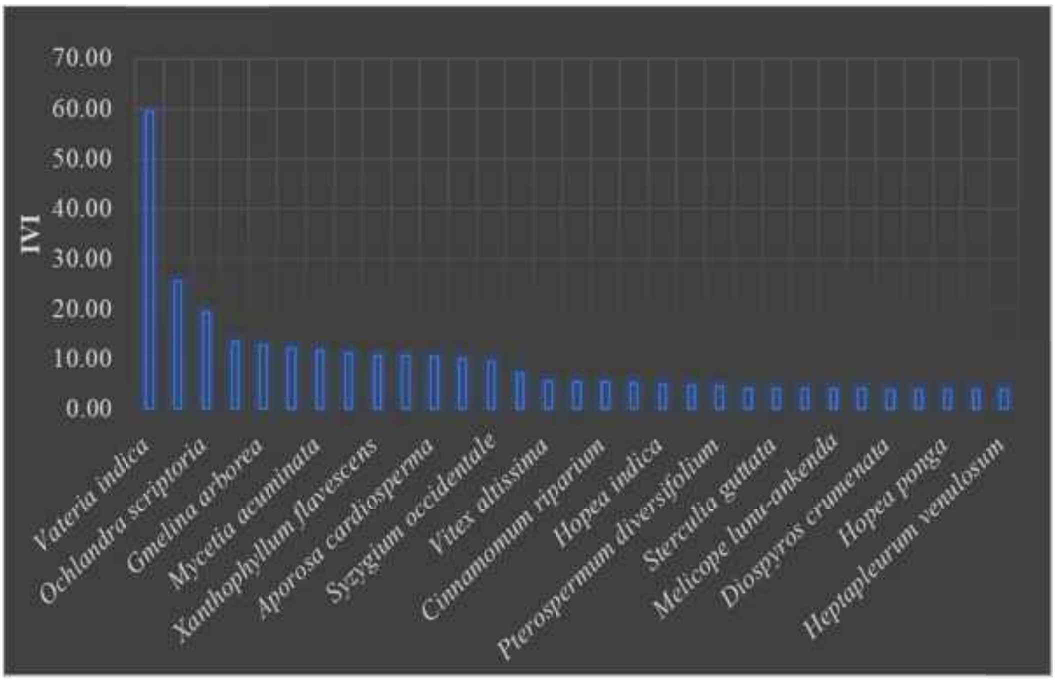


Sl. No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Barringtonia acutangula*	10	1	38.29	20.07	6.06	19.42	45.55
2	*Humboldtia vahliana*	3.33	0.83	61.84	6.69	5.05	31.36	43.1
3	*Syzygium occidentale*	6.5	0.67	14.19	13.04	4.04	7.2	24.28
4	*Vateria indica*	1.17	0.33	25.06	2.34	2.02	12.71	17.07
5	*Mallotus atrovirens*	3.17	0.83	6.89	6.35	5.05	3.49	14.9
6	*Holigarna arnottiana*	1	0.67	10.51	2.01	4.04	5.33	11.38
7	*Lagerstroemia microcarpa*	0.83	0.5	8.45	1.67	3.03	4.28	8.99

Sl. No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
8	*Homonoia riparia*	2	0.67	0.81	4.01	4.04	0.41	8.46
9	*Mallotus resinosus*	1.5	0.33	5.79	3.01	2.02	2.94	7.97
10	*Hopea indica*	0.83	0.33	6.03	1.67	2.02	3.06	6.75
11	*Xanthophyllum flavescens*	1.5	0.33	2.91	3.01	2.02	1.48	6.51
12	*Aporosa cardiosperma*	1	0.5	1.31	2.01	3.03	0.66	5.7
13	*Tetrapilus dioicus*	0.67	0.67	0.62	1.34	4.04	0.31	5.69
14	*Hydnocarpus alpina*	0.5	0.5	2.19	1	3.03	1.11	5.14
15	*Ochlandra scriptoria*	1.33	0.33	0.27	2.68	2.02	0.14	4.83
16	*Litsea coriacea*	1	0.33	1.18	2.01	2.02	0.6	4.63
17	*Cinnamomum malabatrum*	1	0.33	0.4	2.01	2.02	0.2	4.23
18	*Carallia brachiata*	0.5	0.5	0.17	1	3.03	0.08	4.12
19	*Xylia xylocarpa*	0.67	0.33	1.21	1.34	2.02	0.61	3.97
20	*Gymnacranthera farquhariana*	0.67	0.33	1.16	1.34	2.02	0.59	3.94
21	*Dimocarpus longan*	0.67	0.33	0.28	1.34	2.02	0.14	3.5
22	*Elaeocarpus serratus*	0.33	0.33	1.58	0.67	2.02	0.8	3.49
23	*Myristica malabarica*	0.83	0.17	1.41	1.67	1.01	0.72	3.4
24	*Aporosa bourdillonii*	0.67	0.33	0.06	1.34	2.02	0.03	3.39
25	*Cinnamomum riparium*	0.5	0.33	0.2	1	2.02	0.1	3.12
26	*Ficus racemosa*	1	0.17	0.21	2.01	1.01	0.11	3.12
27	*Glochidion ellipticum*	0.33	0.33	0.72	0.67	2.02	0.36	3.05
28	*Fagraea ceilanica*	0.5	0.33	0.03	1	2.02	0.02	3.04
29	*Vitex leucoxylon*	0.83	0.17	0.08	1.67	1.01	0.04	2.72
30	*Lagerstroemia speciosa*	0.33	0.17	0.98	0.67	1.01	0.49	2.17
31	*Baccaurea courtallensis*	0.5	0.17	0.26	1	1.01	0.13	2.15
32	*Terminalia paniculata*	0.33	0.17	0.24	0.67	1.01	0.12	1.8
33	*Garcinia wightii*	0.33	0.17	0.12	0.67	1.01	0.06	1.74
34	*Flacourtia montana*	0.33	0.17	0.08	0.67	1.01	0.04	1.72
35	*Garcinia imbertii*	0.33	0.17	0.06	0.67	1.01	0.03	1.71
36	*Macaranga peltata*	0.33	0.17	0.04	0.67	1.01	0.02	1.7
37	*Prioria pinnata*	0.17	0.17	0.33	0.33	1.01	0.17	1.51
38	*Knema attenuata*	0.17	0.17	0.3	0.33	1.01	0.15	1.49
39	*Bombax ceiba*	0.17	0.17	0.26	0.33	1.01	0.13	1.48
40	*Poeciloneuron indicum*	0.17	0.17	0.2	0.33	1.01	0.1	1.45

Sl. No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
41	*Adina cordifolia*	0.17	0.17	0.19	0.33	1.01	0.1	1.44
42	*Aglaia lawii*	0.17	0.17	0.11	0.33	1.01	0.06	1.4
43	*Ochlandra travancorica*	0.17	0.17	0.06	0.33	1.01	0.03	1.38
44	*Artocarpus hirsutus*	0.17	0.17	0.04	0.33	1.01	0.02	1.37
45	*Gmelina arborea*	0.17	0.17	0.02	0.33	1.01	0.01	1.35
46	*Leea asiatica*	0.17	0.17	0.01	0.33	1.01	0.01	1.35
47	*Turpinia malabarica*	0.17	0.17	0.01	0.33	1.01	0	1.35
48	*Mussaenda frondosa*	0.17	0.17	0.01	0.33	1.01	0	1.35
49	*Meiogyne pannosa*	0.17	0.17	0.01	0.33	1.01	0	1.35
50	*Capparis baducca*	0.17	0.17	0.01	0.33	1.01	0	1.35
51	*Sterculia guttata*	0.17	0.17	0.01	0.33	1.01	0	1.35
Total		49.83	16.5	197.17	100	100	100	300

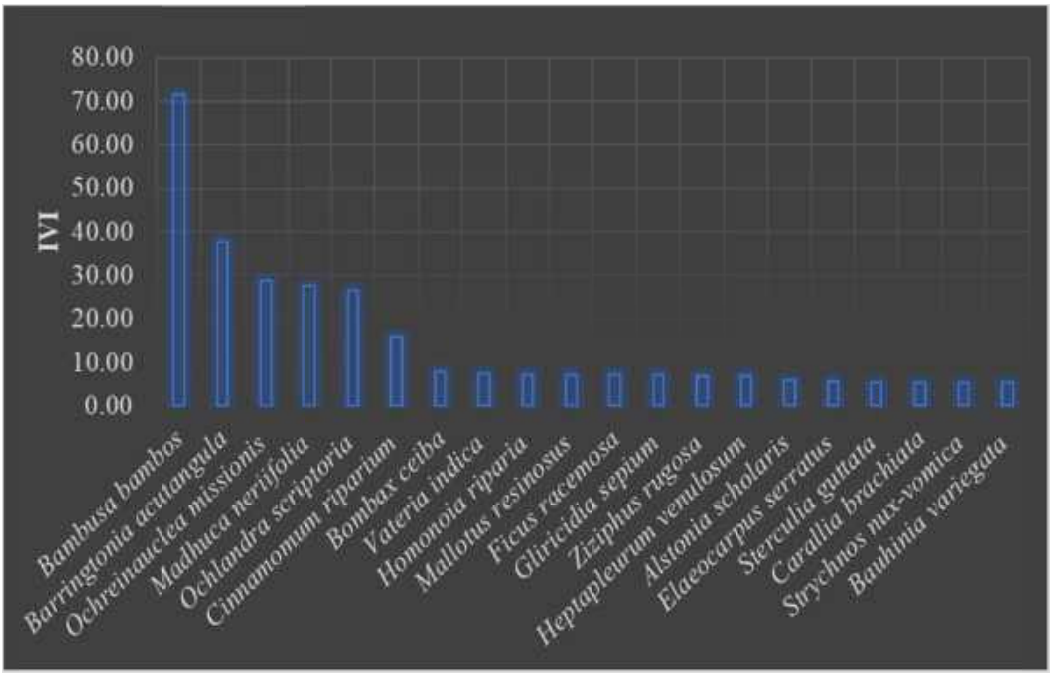
16. Dominant species associations in Cluster - 6d



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Vateria indica*	3	1	12.4	8.96	4.76	45.6	59.32
2	*Holigarna arnottiana*	2	1	4.04	5.97	4.76	14.79	25.53
3	*Ochlandra scriptoria*	1	1	3.18	2.99	4.76	11.66	19.4

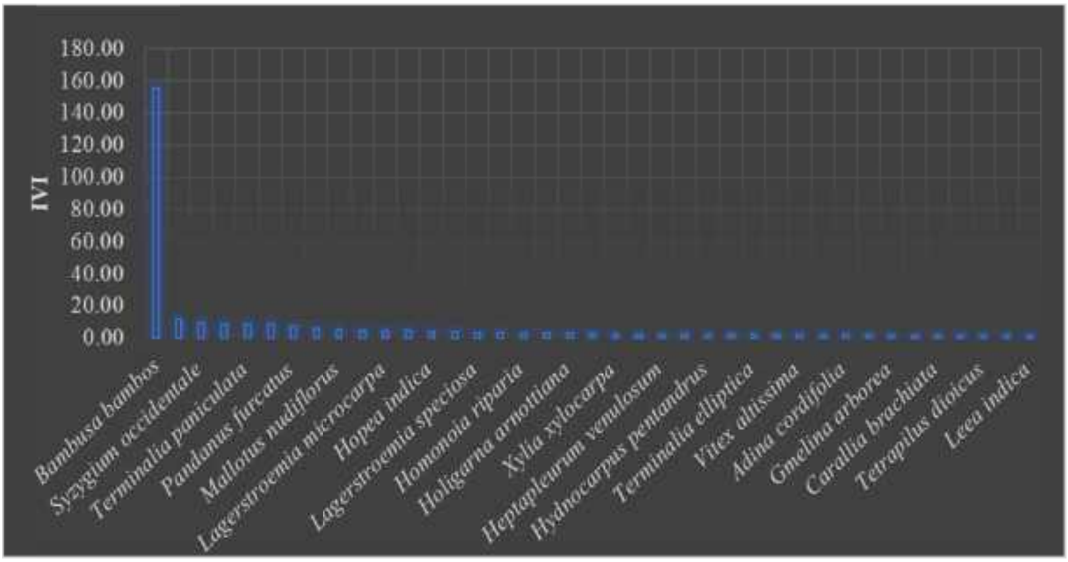
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
4	*Myristica beddomei*	1.5	1	1.17	4.48	4.76	4.28	13.52
5	*Gmelina arborea*	1	1	1.39	2.99	4.76	5.1	12.85
6	*Madhuca neriifolia*	2	1	0.41	5.97	4.76	1.52	12.25
7	*Mycetia acuminata*	3	0.5	0.1	8.96	2.38	0.36	11.7
8	*Garcinia cambogioides var. cambogioides*	2	1	0.09	5.97	4.76	0.33	11.07
9	*Xanthophyllum flavescens*	2	0.5	0.66	5.97	2.38	2.42	10.77
10	*Bombax ceiba*	1	1	0.79	2.99	4.76	2.9	10.64
11	*Aporosa cardiosperma*	1.5	1	0.32	4.48	4.76	1.16	10.4
12	*Humboldtia vahliana*	1	1	0.61	2.99	4.76	2.24	9.99
13	*Syzygium occidentale*	1.5	1	0.05	4.48	4.76	0.2	9.44
14	*Barringtonia acutangula*	1.5	0.5	0.07	4.48	2.38	0.27	7.13
15	*Vitex altissima*	0.5	0.5	0.48	1.49	2.38	1.75	5.63
16	*Baccaurea courtallensis*	1	0.5	0.03	2.99	2.38	0.1	5.46
17	*Cinnamomum riparium*	1	0.5	0.01	2.99	2.38	0.05	5.42
18	*Dipterocarpus indicus*	0.5	0.5	0.35	1.49	2.38	1.29	5.16
19	*Hopea indica*	0.5	0.5	0.3	1.49	2.38	1.11	4.98
20	*Monoon fragrans*	0.5	0.5	0.23	1.49	2.38	0.84	4.72
21	*Pterospermum diversifolium*	0.5	0.5	0.16	1.49	2.38	0.57	4.45
22	*Prioria pinnata*	0.5	0.5	0.08	1.49	2.38	0.29	4.17
23	*Sterculia guttata*	0.5	0.5	0.08	1.49	2.38	0.29	4.17
24	*Xylia xylocarpa*	0.5	0.5	0.06	1.49	2.38	0.24	4.11
25	*Melicope lunu-ankenda*	0.5	0.5	0.05	1.49	2.38	0.2	4.07
26	*Dalbergia lanceolaria*	0.5	0.5	0.04	1.49	2.38	0.16	4.04
27	*Diospyros crumenata*	0.5	0.5	0.03	1.49	2.38	0.11	3.99
28	*Mangifera indica*	0.5	0.5	0.02	1.49	2.38	0.06	3.94
29	*Hopea ponga*	0.5	0.5	0.01	1.49	2.38	0.04	3.91
30	*Mallotus atrovirens*	0.5	0.5	0.01	1.49	2.38	0.04	3.91
31	*Heptapleurum venulosum*	0.5	0.5	0.01	1.49	2.38	0.03	3.9
Total		33.5	21.00	27.28	100	100	100	300

17. Dominant species associations in Cluster - 6e



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Bambusa bambos*	2	0.67	8.84	10	7.41	54.09	71.49
2	*Barringtonia acutangula*	3.67	1.00	1.35	18.33	11.11	8.26	37.71
3	*Ochreinauclea missionis*	2.33	0.67	1.58	11.67	7.41	9.68	28.76
4	*Madhuca neriifolia*	2	0.67	1.66	10	7.41	10.12	27.53
5	*Ochlandra scriptoria*	1.33	1.00	1.44	6.67	11.11	8.79	26.57
6	*Cinnamomum riparium*	1.67	0.33	0.62	8.33	3.7	3.79	15.83
7	*Bombax ceiba*	0.67	0.33	0.16	3.33	3.7	0.98	8.02
8	*Vateria indica*	0.33	0.33	0.36	1.67	3.7	2.19	7.56
9	*Homonoia riparia*	0.67	0.33	0.04	3.33	3.7	0.26	7.3
10	*Mallotus resinosus*	0.67	0.33	0.04	3.33	3.7	0.25	7.29
11	*Ficus racemosa*	0.67	0.33	0.01	3.33	3.7	0.09	7.12
12	*Gliricidia sepium*	0.67	0.33	0.01	3.33	3.7	0.08	7.12
13	*Ziziphus rugosa*	0.67	0.33	0.01	3.33	3.7	0.04	7.08
14	*Heptapleurum venulosum*	0.67	0.33	0.01	3.33	3.7	0.03	7.07
15	*Alstonia scholaris*	0.33	0.33	0.1	1.67	3.7	0.61	5.98
16	*Elaeocarpus serratus*	0.33	0.33	0.06	1.67	3.7	0.39	5.76
17	*Sterculia guttata*	0.33	0.33	0.02	1.67	3.7	0.13	5.5
18	*Carallia brachiata*	0.33	0.33	0.01	1.67	3.7	0.08	5.45
19	*Strychnos nux-vomica*	0.33	0.33	0.01	1.67	3.7	0.07	5.44
20	*Bauhinia variegata*	0.33	0.33	0.01	1.67	3.7	0.04	5.41
Total		20	9.00	16.35	100	100	100	300

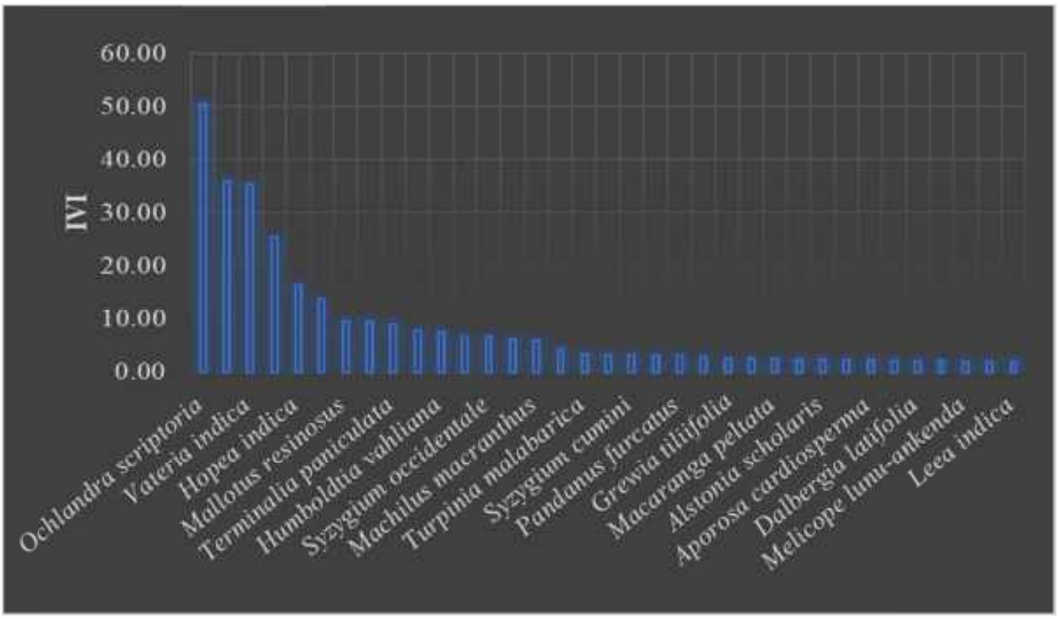
18. Dominant species associations in Cluster - 7a



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Bambusa bambos*	26.29	1	116	59.16	11.29	84.61	155.07
2	*Macaranga peltata*	1.14	0.57	3.62	2.57	6.45	2.63	11.65
3	*Syzygium occidentale*	2.29	0.29	1.42	5.14	3.23	1.03	9.4
4	*Madhuca neriifolia*	1.29	0.29	3.9	2.89	3.23	2.84	8.96
5	*Terminalia paniculata*	0.71	0.57	1.2	1.61	6.45	0.88	8.94
6	*Tetrameles nudiflora*	0.43	0.43	3.86	0.96	4.84	2.8	8.61
7	*Pandanus furcatus*	1.71	0.29	0.62	3.86	3.23	0.45	7.53
8	*Ochlandra scriptoria*	1.71	0.14	0.07	3.86	1.61	0.05	5.52
9	*Mallotus nudiflorus*	0.71	0.29	0.25	1.61	3.23	0.18	5.02
10	*Humboldtia vahliana*	0.43	0.29	0.92	0.96	3.23	0.67	4.86
11	*Lagerstroemia microcarpa*	0.43	0.29	0.85	0.96	3.23	0.62	4.81
12	*Ficus tsjahela*	0.29	0.29	0.96	0.64	3.23	0.7	4.57
13	*Hopea indica*	0.29	0.29	0.58	0.64	3.23	0.42	4.29
14	*Stereospermum colais*	0.29	0.29	0.14	0.64	3.23	0.1	3.97
15	*Lagerstroemia speciosa*	0.57	0.14	0.66	1.29	1.61	0.48	3.38
16	*Mallotus resinosus*	0.71	0.14	0.16	1.61	1.61	0.11	3.33
17	*Homonoia riparia*	0.57	0.14	0.08	1.29	1.61	0.06	2.95
18	*Mallotus atrovirens*	0.43	0.14	0.39	0.96	1.61	0.29	2.86
19	*Holigarna arnottiana*	0.43	0.14	0.06	0.96	1.61	0.05	2.62
20	*Barringtonia acutangula*	0.43	0.14	0.04	0.96	1.61	0.03	2.61
21	*Xylia xylocarpa*	0.29	0.14	0.16	0.64	1.61	0.11	2.37

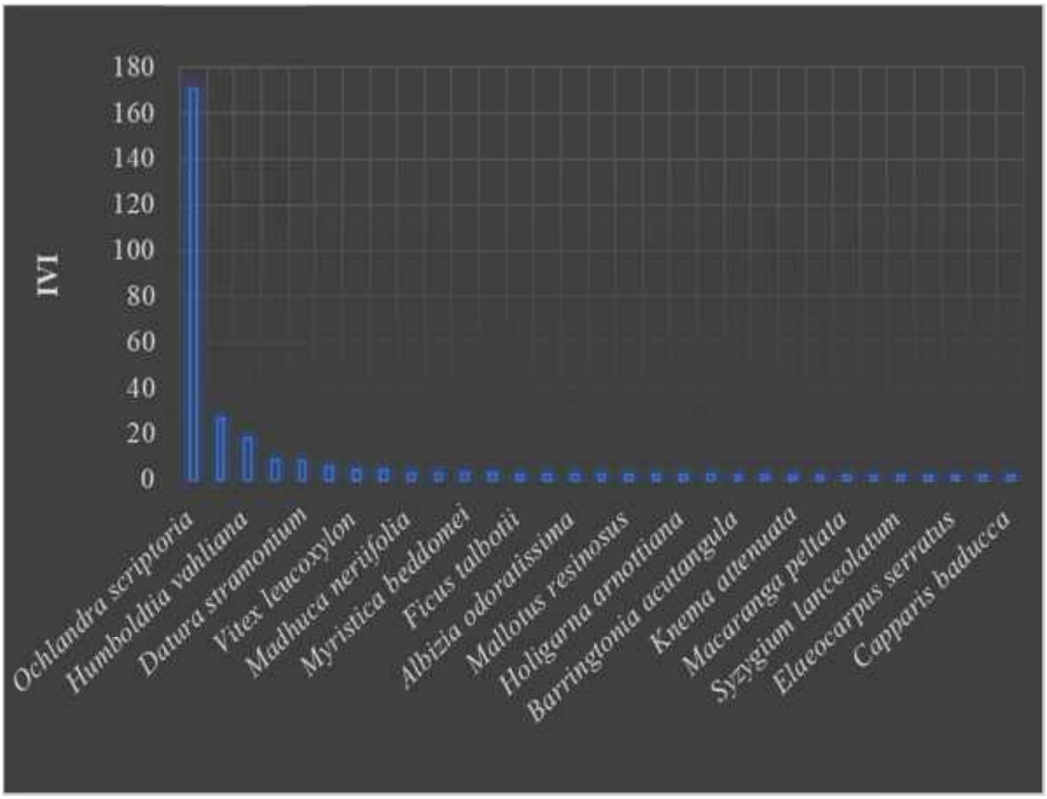
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
22	*Salix tetrasperma*	0.29	0.14	0.03	0.64	1.61	0.02	2.28
23	*Heptapleurum venulosum*	0.29	0.14	0.02	0.64	1.61	0.02	2.27
24	*Vitex leucoxylon*	0.29	0.14	0.02	0.64	1.61	0.01	2.27
25	*Hydnocarpus pentandrus*	0.14	0.14	0.36	0.32	1.61	0.26	2.19
26	*Prioria pinnata*	0.14	0.14	0.26	0.32	1.61	0.19	2.12
27	*Terminalia elliptica*	0.14	0.14	0.14	0.32	1.61	0.1	2.04
28	*Alstonia scholaris*	0.14	0.14	0.07	0.32	1.61	0.05	1.99
29	*Vitex altissima*	0.14	0.14	0.07	0.32	1.61	0.05	1.99
30	*Datura stramonium*	0.14	0.14	0.06	0.32	1.61	0.04	1.98
31	*Adina cordifolia*	0.14	0.14	0.06	0.32	1.61	0.04	1.98
32	*Arenga wightii*	0.14	0.14	0.04	0.32	1.61	0.03	1.96
33	*Gmelina arborea*	0.14	0.14	0.03	0.32	1.61	0.02	1.95
34	*Machilus macranthus*	0.14	0.14	0.02	0.32	1.61	0.02	1.95
35	*Carallia brachiata*	0.14	0.14	0.01	0.32	1.61	0.01	1.94
36	*Erythrina variegata*	0.14	0.14	0.01	0.32	1.61	0.01	1.94
37	*Tetrapilus dioicus*	0.14	0.14	0.01	0.32	1.61	0.01	1.94
38	*Aporosa cardiosperma*	0.14	0.14	0.01	0.32	1.61	0.01	1.94
39	*Leea indica*	0.14	0.14	0.01	0.32	1.61	0.01	1.94
Total		44.42	8.85	137.52	100	100	100	300

19. Dominant species associations in Cluster - 7b



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Ochlandra scriptoria*	29.25	1	4.67	36.34	6.9	7.22	50.45
2	*Madhuca neriifolia*	5	1	14.8	6.21	6.9	22.89	36
3	*Vateria indica*	7.5	0.25	15.8	9.32	1.72	24.46	35.5
4	*Barringtonia acutangula*	7.5	1	5.97	9.32	6.9	9.23	25.44
5	*Hopea indica*	1.5	0.75	6.01	1.86	5.17	9.29	16.33
6	*Lagerstroemia microcarpa*	2.25	0.5	4.92	2.8	3.45	7.6	13.84
7	*Mallotus resinosus*	2	0.75	1.24	2.48	5.17	1.91	9.57
8	*Ochlandra travancorica*	4.25	0.5	0.51	5.28	3.45	0.78	9.51
9	*Terminalia paniculata*	1.75	0.75	1.04	2.17	5.17	1.61	8.96
10	*Ficus racemosa*	1.25	0.75	0.77	1.55	5.17	1.19	7.92
11	*Humboldtia vahliana*	1	0.25	2.98	1.24	1.72	4.61	7.57
12	*Heptapleurum venulosum*	2.5	0.5	0.19	3.11	3.45	0.3	6.85
13	*Syzygium occidentale*	2.25	0.5	0.36	2.8	3.45	0.56	6.81
14	*Helicteres isora*	2	0.5	0.24	2.48	3.45	0.37	6.31
15	*Machilus macranthus*	1	0.5	0.91	1.24	3.45	1.41	6.1
16	*Elaeocarpus variabilis*	0.75	0.25	1.15	0.93	1.72	1.78	4.43
17	*Turpinia malabarica*	0.25	0.25	0.91	0.31	1.72	1.41	3.44
18	*Leea guineensis*	1.25	0.25	0.02	1.55	1.72	0.03	3.31
19	*Syzygium cumini*	0.25	0.25	0.82	0.31	1.72	1.26	3.29
20	*Bambusa bambos*	1	0.25	0.2	1.24	1.72	0.31	3.28
21	*Pandanus furcatus*	1	0.25	0.03	1.24	1.72	0.05	3.02
22	*Diospyros buxifolia*	0.75	0.25	0.21	0.93	1.72	0.32	2.97
23	*Grewia tiliifolia*	0.5	0.25	0.16	0.62	1.72	0.25	2.59
24	*Dillenia pentagyna*	0.5	0.25	0.09	0.62	1.72	0.14	2.49
25	*Macaranga peltata*	0.5	0.25	0.05	0.62	1.72	0.08	2.43
26	*Peltophorum pterocarpum*	0.5	0.25	0.03	0.62	1.72	0.04	2.39
27	*Alstonia scholaris*	0.25	0.25	0.16	0.31	1.72	0.24	2.28
28	*Glochidion zeylanicum var. zeylanicum*	0.25	0.25	0.15	0.31	1.72	0.22	2.26
29	*Aporosa cardiosperma*	0.25	0.25	0.14	0.31	1.72	0.22	2.26
30	*Tetrapilus dioicus*	0.25	0.25	0.06	0.31	1.72	0.09	2.12
31	*Dalbergia latifolia*	0.25	0.25	0.04	0.31	1.72	0.06	2.09
32	*Bombax ceiba*	0.25	0.25	0.02	0.31	1.72	0.02	2.06
33	*Melicope lunu-ankenda*	0.25	0.25	0.01	0.31	1.72	0.02	2.05
34	*Strychnos nux-vomica*	0.25	0.25	0.01	0.31	1.72	0.02	2.05
35	*Leea indica*	0.25	0.25	0.01	0.31	1.72	0.01	2.05
Total		80.50	14.50	64.71	100	100	100	300

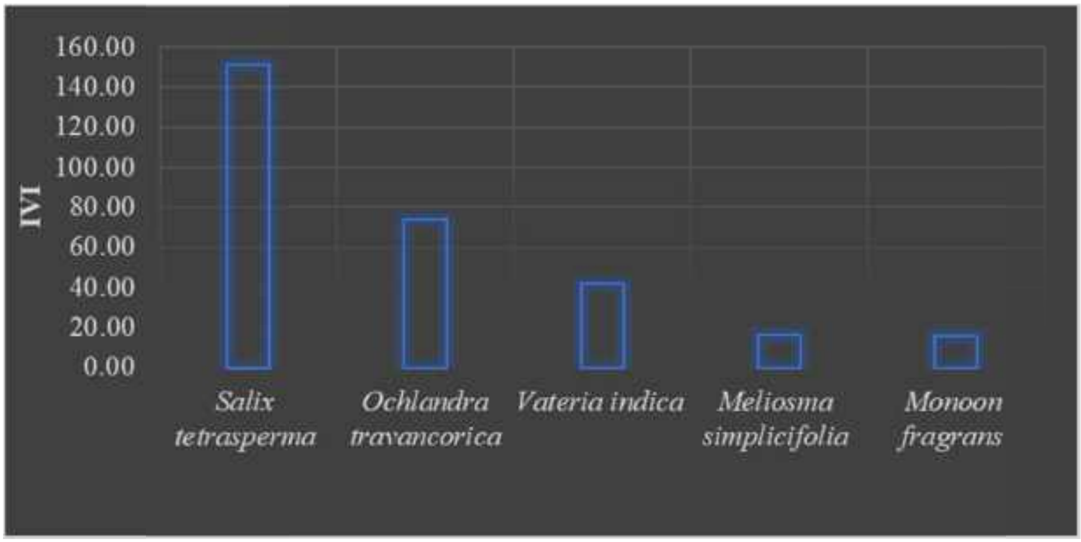
20. **Dominant species associations in Cluster - 7c**



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Ochlandra scriptoria*	111.9	1	260	81.06	13.21	76.26	170.52
2	*Bambusa bambos*	13	0.71	28.4	9.42	9.44	8.34	27.2
3	*Humboldtia vahliana*	3.57	0.43	34.5	2.59	5.66	10.12	18.37
4	*Salix tetrasperma*	1.14	0.57	1.39	0.83	7.55	0.41	8.78
5	*Datura stramonium*	0.57	0.57	0.87	0.41	7.55	0.25	8.22
6	*Tetrapilus dioicus*	0.43	0.43	0.24	0.31	5.66	0.07	6.04
7	*Vitex leucoxylon*	1	0.29	0.41	0.72	3.77	0.12	4.62
8	*Cinnamomum riparium*	0.71	0.29	0.28	0.52	3.77	0.08	4.37
9	*Madhuca neriifolia*	0.57	0.14	2.24	0.41	1.89	0.66	2.96
10	*Vateria indica*	0.29	0.14	2.53	0.21	1.89	0.74	2.84
11	*Myristica beddomei*	0.71	0.14	1.41	0.52	1.89	0.41	2.82
12	*Holigarna grahamii*	0.29	0.14	2.36	0.21	1.89	0.69	2.79
13	*Ficus talbotii*	0.14	0.14	1.18	0.1	1.89	0.35	2.34
14	*Hopea indica*	0.14	0.14	1.03	0.1	1.89	0.3	2.29
15	*Albizia odoratissima*	0.29	0.14	0.66	0.21	1.89	0.19	2.29
16	*Mallotus nudiflorus*	0.43	0.14	0.21	0.31	1.89	0.06	2.26
17	*Mallotus resinosus*	0.43	0.14	0.08	0.31	1.89	0.02	2.22
18	*Hopea ponga*	0.29	0.14	0.35	0.21	1.89	0.1	2.2
19	*Holigarna arnottiana*	0.14	0.14	0.55	0.1	1.89	0.16	2.15

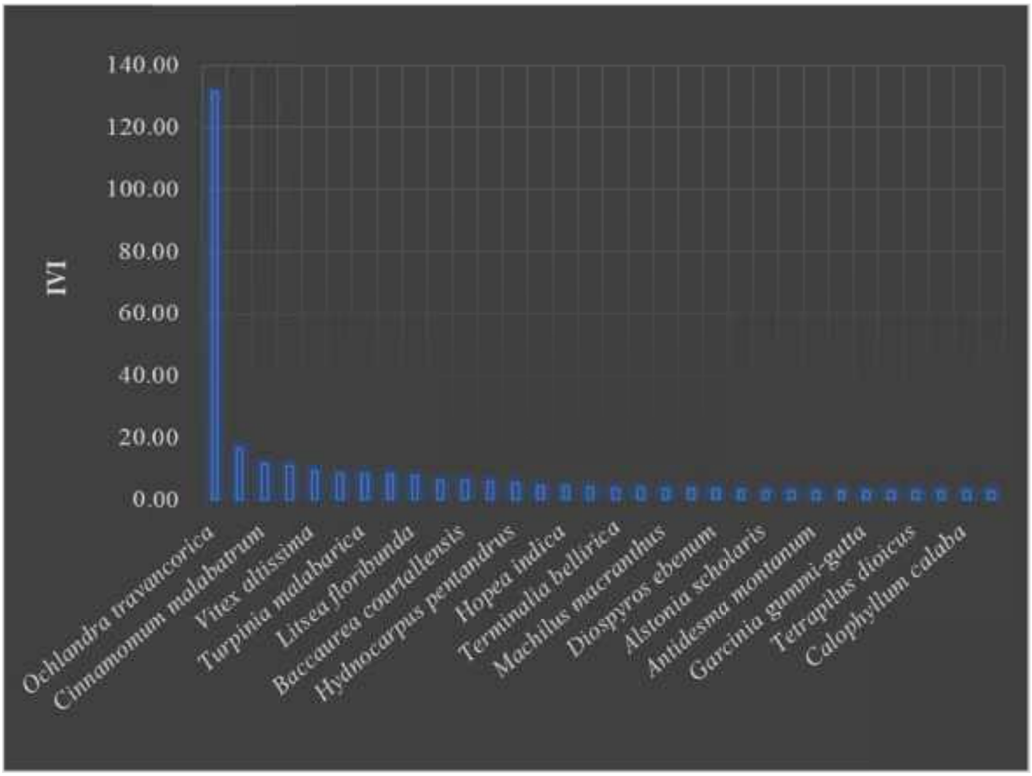
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
20	*Hydnocarpus alpina*	0.14	0.14	0.55	0.1	1.89	0.16	2.15
21	*Barringtonia acutangula*	0.29	0.14	0.04	0.21	1.89	0.01	2.11
22	*Crateva magna*	0.29	0.14	0.03	0.21	1.89	0.01	2.1
23	*Knema attenuata*	0.14	0.14	0.3	0.1	1.89	0.09	2.08
24	*Vitex altissima*	0.14	0.14	0.26	0.1	1.89	0.08	2.07
25	*Macaranga peltata*	0.14	0.14	0.26	0.1	1.89	0.08	2.07
26	*Glochidion zeylanicum var. zeylanicum*	0.14	0.14	0.23	0.1	1.89	0.07	2.06
27	*Syzygium lanceolatum*	0.14	0.14	0.21	0.1	1.89	0.06	2.05
28	*Pongamia pinnata*	0.14	0.14	0.16	0.1	1.89	0.05	2.04
29	*Elaeocarpus serratus*	0.14	0.14	0.07	0.1	1.89	0.02	2.01
30	*Cyathocalyx zeylanicus*	0.14	0.14	0.05	0.1	1.89	0.01	2
31	*Capparis baducca*	0.14	0.14	0.01	0.1	1.89	0	1.99
Total		138	7.57	340.98	100	100	100	300

21. Dominant species associations in Cluster - 8a



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Salix tetrasperma*	6.5	1	7.29	43.33	25	82.88	151.21
2	*Ochlandra travancorica*	6	1	0.81	40	25	9.15	74.15
3	*Vateria indica*	1.5	1	0.64	10	25	7.25	42.25
4	*Meliosma simplicifolia*	0.5	0.5	0.05	3.33	12.5	0.62	16.46
5	*Monoon fragrans*	0.5	0.5	0.01	3.33	12.5	0.1	15.93
Total		15	4	8.79	100	100	100	300

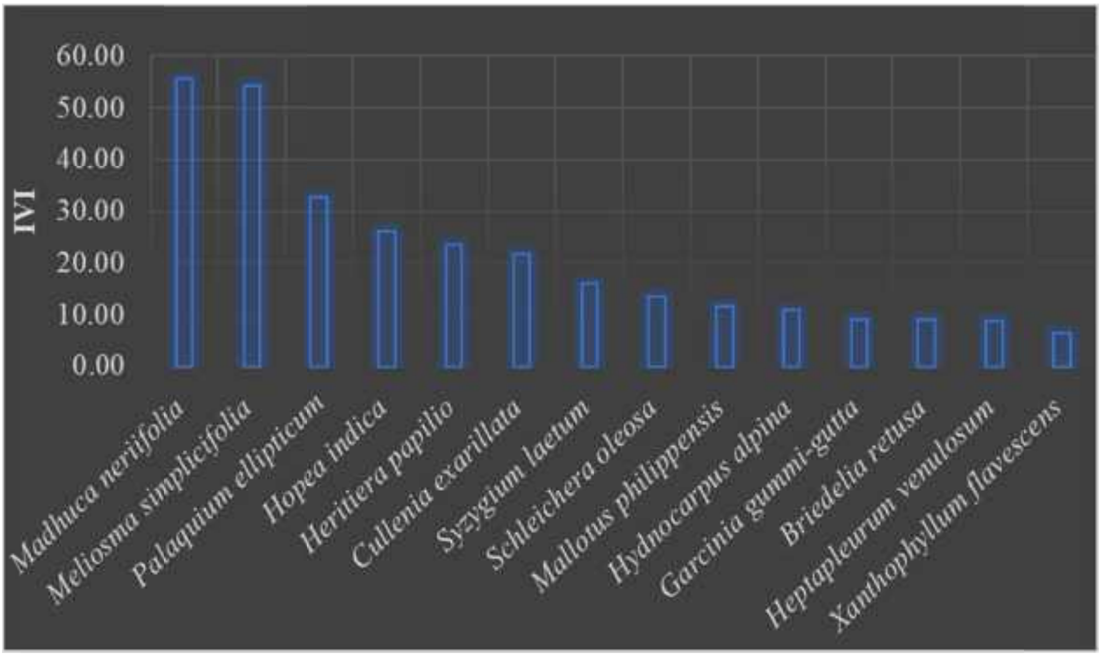
22. Dominant species associations in Cluster - 8b



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Ochlandra travancorica*	46.67	1	14.9	66.99	7.32	57.44	131.74
2	*Mallotus resinosus*	2.67	0.33	2.74	3.83	2.44	10.58	16.84
3	*Cinnamomum malabatrum*	2.67	0.67	0.77	3.83	4.88	2.97	11.67
4	*Lagerstroemia microcarpa*	1	0.33	1.87	1.44	2.44	7.19	11.06
5	*Vitex altissima*	1	0.67	0.73	1.44	4.88	2.8	9.11
6	*Vateria indica*	1.67	0.67	0.3	2.39	4.88	1.16	8.43
7	*Turpinia malabarica*	1.33	0.33	1.03	1.91	2.44	3.96	8.31
8	*Knema attenuata*	1	0.67	0.49	1.44	4.88	1.89	8.2
9	*Litsea floribunda*	1.33	0.67	0.22	1.91	4.88	0.87	7.66
10	*Lagerstroemia speciosa*	1	0.33	0.58	1.44	2.44	2.22	6.1
11	*Baccaurea courtallensis*	0.67	0.67	0.06	0.96	4.88	0.25	6.08
12	*Leea indica*	0.67	0.67	0.04	0.96	4.88	0.15	5.99
13	*Hydnocarpus pentandrus*	0.33	0.33	0.61	0.48	2.44	2.34	5.26
14	*Elaeocarpus tuberculatus*	0.33	0.33	0.39	0.48	2.44	1.49	4.4
15	*Hopea indica*	0.67	0.33	0.24	0.96	2.44	0.94	4.34
16	*Aporosa cardiosperma*	0.67	0.33	0.17	0.96	2.44	0.65	4.05
17	*Terminalia bellirica*	0.33	0.33	0.24	0.48	2.44	0.92	3.84
18	*Mallotus atrovirens*	0.67	0.33	0.07	0.96	2.44	0.28	3.67
19	*Machilus macranthus*	0.67	0.33	0.04	0.96	2.44	0.14	3.53

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
20	*Spondias pinnata*	0.33	0.33	0.14	0.48	2.44	0.55	3.47
21	*Diospyros ebenum*	0.33	0.33	0.11	0.48	2.44	0.43	3.35
22	*Elaeocarpus variabilis*	0.33	0.33	0.08	0.48	2.44	0.32	3.24
23	*Alstonia scholaris*	0.33	0.33	0.02	0.48	2.44	0.09	3.01
24	*Hydnocarpus alpina*	0.33	0.33	0.02	0.48	2.44	0.09	3
25	*Antidesma montanum*	0.33	0.33	0.02	0.48	2.44	0.06	2.98
26	*Schleichera oleosa*	0.33	0.33	0.01	0.48	2.44	0.05	2.97
27	*Garcinia gummi-gutta*	0.33	0.33	0.01	0.48	2.44	0.04	2.96
28	*Mallotus philippensis*	0.33	0.33	0.01	0.48	2.44	0.04	2.95
29	*Tetrapilus dioicus*	0.33	0.33	0.01	0.48	2.44	0.04	2.95
30	*Aglaia edulis*	0.33	0.33	0.01	0.48	2.44	0.03	2.95
31	*Calophyllum calaba*	0.33	0.33	0.01	0.48	2.44	0.03	2.95
32	*Myristica beddomei*	0.33	0.33	0.01	0.48	2.44	0.02	2.93
Total		69.66	13.66	25.93	100	100	100	300

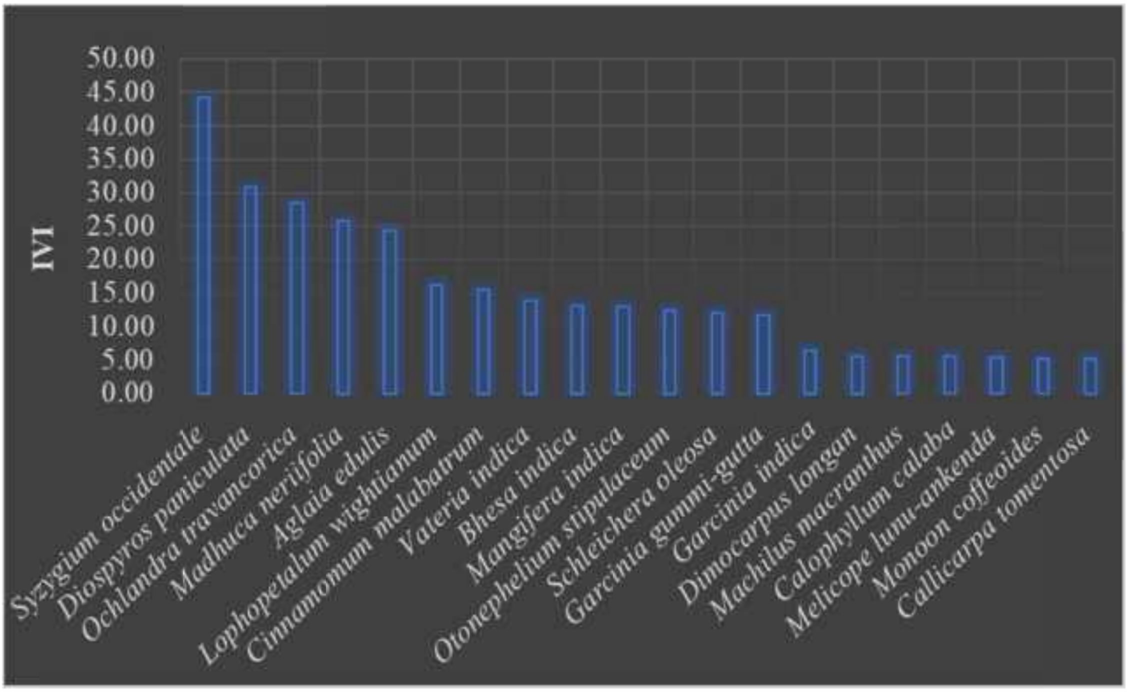
23. Dominant species associations in Cluster - 9a



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Madhuca neriifolia*	2.75	**1**	11.7	17.19	11.11	27.35	55.64
2	*Meliosma simplicifolia*	4	1	7.77	25	11.11	18.11	54.22
3	*Palaquium ellipticum*	1.25	0.75	7.07	7.81	8.33	16.46	32.61
4	*Hopea indica*	1	0.75	5.01	6.25	8.33	11.67	26.25
5	*Heritiera papilio*	1	0.75	3.88	6.25	8.33	9.04	23.62

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
6	*Cullenia exarillata*	1	0.75	3.11	6.25	8.33	7.25	21.83
7	*Syzygium laetum*	1	0.75	0.65	6.25	8.33	1.52	16.1
8	*Schleichera oleosa*	0.75	0.5	1.38	4.69	5.56	3.21	13.45
9	*Mallotus philippensis*	0.75	0.5	0.64	4.69	5.56	1.49	11.73
10	*Hydnocarpus alpina*	0.5	0.5	0.98	3.13	5.56	2.29	10.97
11	*Garcinia gummi-gutta*	0.5	0.5	0.17	3.13	5.56	0.41	9.09
12	*Briedelia retusa*	0.5	0.5	0.17	3.13	5.56	0.4	9.08
13	*Heptapleurum venulosum*	0.5	0.5	0.06	3.13	5.56	0.14	8.82
14	*Xanthophyllum flavescens*	0.5	0.25	0.29	3.13	2.78	0.67	6.57
Total		16	9	42.91	100	100	100	300

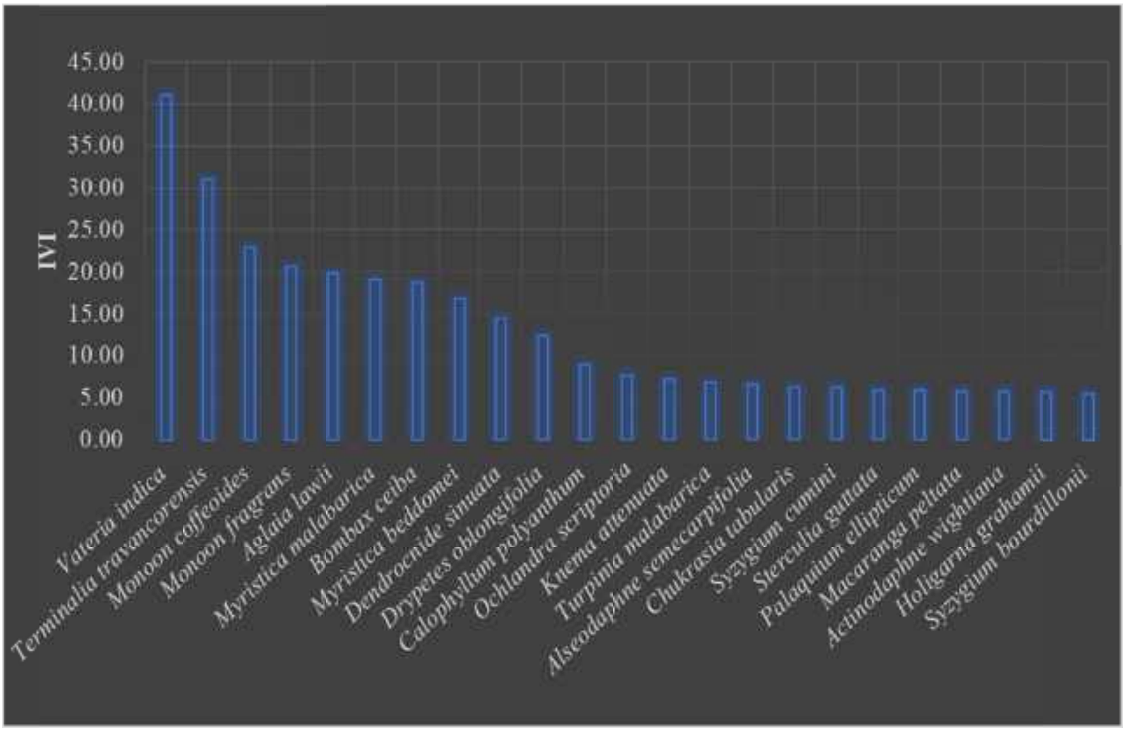
24. **Dominant species associations in Cluster - 9b**



Sl No.	Name of Species	D	F	BA (m2)	RD	RF	RBA	IVI
1	*Syzygium occidentale*	7.00	1.00	3.11	22.58	7.14	14.43	44.15
2	*Diospyros paniculata*	3.00	1.00	3.02	9.68	7.14	14.02	30.84
3	*Ochlandra travancorica*	4.00	0.50	2.59	12.90	3.57	12.00	28.48
4	*Madhuca neriifolia*	1.50	1.00	2.98	4.84	7.14	13.84	25.82
5	*Aglaia edulis*	2.00	1.00	2.30	6.45	7.14	10.65	24.25
6	*Lophopetalum wightianum*	0.50	0.50	2.37	1.61	3.57	11.01	16.20
7	*Cinnamomum malabatrum*	2.00	1.00	0.41	6.45	7.14	1.90	15.50
8	*Vateria indica*	1.50	0.50	1.16	4.84	3.57	5.39	13.80
9	*Bhesa indica*	1.00	0.50	1.35	3.23	3.57	6.27	13.07

Sl No.	Name of Species	D	F	BA (m2)	RD	RF	RBA	IVI
10	*Mangifera indica*	1.50	1.00	0.21	4.84	7.14	0.99	12.98
11	*Otonephelium stipulaceum*	1.50	1.00	0.10	4.84	7.14	0.45	12.43
12	*Schleichera oleosa*	1.00	1.00	0.35	3.23	7.14	1.63	12.00
13	*Garcinia gummi-gutta*	1.00	0.50	1.05	3.23	3.57	4.87	11.66
14	*Garcinia indica*	0.50	0.50	0.28	1.61	3.57	1.31	6.49
15	*Dimocarpus longan*	0.50	0.50	0.07	1.61	3.57	0.33	5.52
16	*Machilus macranthus*	0.50	0.50	0.07	1.61	3.57	0.32	5.50
17	*Calophyllum calaba*	0.50	0.50	0.07	1.61	3.57	0.32	5.50
18	*Melicope lunu-ankenda*	0.50	0.50	0.04	1.61	3.57	0.20	5.39
19	*Monoon coffeoides*	0.50	0.50	0.01	1.61	3.57	0.05	5.23
20	*Callicarpa tomentosa*	0.50	0.50	0.01	1.61	3.57	0.02	5.21
Total		31	14	21.55	100	100	100	300

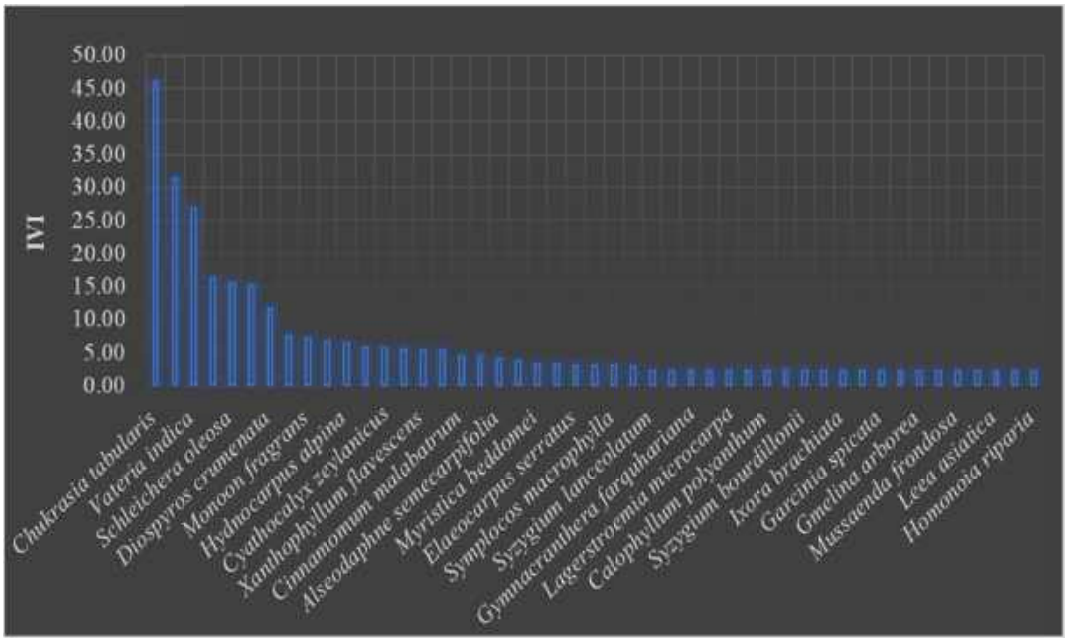
25. Dominant species associations in Cluster - 9c



Sl. No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Vateria indica*	2.5	1	3.76	10.42	6.67	24.03	41.12
2	*Terminalia travancorensis*	1	0.5	3.68	4.17	3.33	23.54	31.04
3	*Monoon coffeoides*	2.5	1	0.9	10.42	6.67	5.78	22.87

Sl. No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
4	*Monoon fragrans*	2	1	0.88	8.33	6.67	5.65	20.65
5	*Aglaia lawii*	2	1	0.76	8.33	6.67	4.83	19.83
6	*Myristica malabarica*	2	1	0.63	8.33	6.67	4.02	19.02
7	*Bombax ceiba*	0.5	0.5	2.07	2.08	3.33	13.24	18.66
8	*Myristica beddomei*	1.5	1	0.6	6.25	6.67	3.85	16.77
9	*Dendrocnide sinuata*	1.5	1	0.24	6.25	6.67	1.54	14.46
10	*Drypetes oblongifolia*	1.5	0.5	0.44	6.25	3.33	2.81	12.4
11	*Calophyllum polyanthum*	0.5	0.5	0.54	2.08	3.33	3.44	8.86
12	*Ochlandra scriptoria*	1	0.5	0.01	4.17	3.33	0.08	7.58
13	*Knema attenuata*	0.5	0.5	0.26	2.08	3.33	1.69	7.1
14	*Turpinia malabarica*	0.5	0.5	0.21	2.08	3.33	1.37	6.79
15	*Alseodaphne semecarpifolia*	0.5	0.5	0.17	2.08	3.33	1.07	6.49
16	*Chukrasia tabularis*	0.5	0.5	0.11	2.08	3.33	0.73	6.15
17	*Syzygium cumini*	0.5	0.5	0.11	2.08	3.33	0.73	6.15
18	*Sterculia guttata*	0.5	0.5	0.06	2.08	3.33	0.41	5.83
19	*Palaquium ellipticum*	0.5	0.5	0.06	2.08	3.33	0.36	5.78
20	*Macaranga peltata*	0.5	0.5	0.05	2.08	3.33	0.31	5.73
21	*Actinodaphne wightiana*	0.5	0.5	0.03	2.08	3.33	0.22	5.63
22	*Holigarna grahamii*	0.5	0.5	0.03	2.08	3.33	0.22	5.63
23	*Syzygium bourdillonii*	0.5	0.5	0.01	2.08	3.33	0.07	5.48
Total		24	15	15.63	100	100	100	300

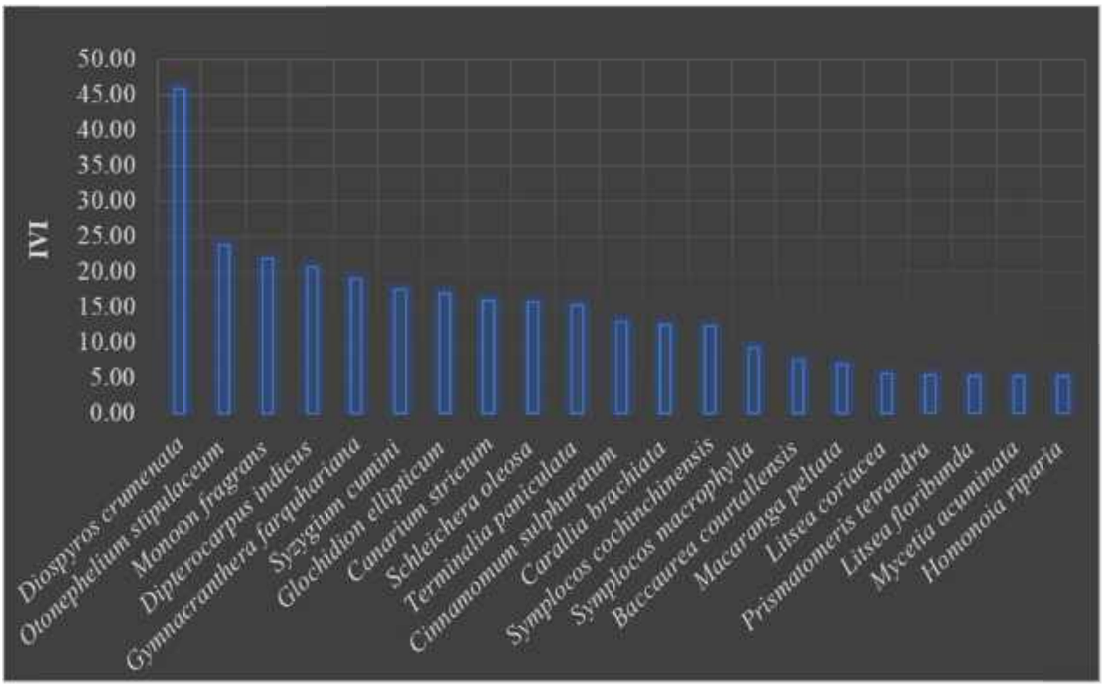
26. **Dominant species associations in Cluster - 9d**



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Chukrasia tabularis*	2.5	1	27	7.74	5.56	32.79	46.08
2	*Dysoxylum malabaricum*	2.25	1	15.5	6.97	5.56	18.88	31.4
3	*Vateria indica*	2.5	1	11.2	7.74	5.56	13.65	26.95
4	*Baccaurea courtallensis*	3	1	1.22	9.29	5.56	1.48	16.32
5	*Schleichera oleosa*	2	1	3.08	6.19	5.56	3.74	15.49
6	*Atuna travancorica*	2.25	0.5	4.57	6.97	2.78	5.56	15.3
7	*Diospyros crumenata*	1	0.5	4.89	3.1	2.78	5.95	11.82
8	*Knema attenuata*	1	0.5	1.34	3.1	2.78	1.63	7.5
9	*Monoon fragrans*	0.75	0.5	1.72	2.32	2.78	2.09	7.19
10	*Elaeocarpus variabilis*	0.75	0.5	1.29	2.32	2.78	1.56	6.66
11	*Hydnocarpus alpina*	1.5	0.25	0.31	4.64	1.39	0.37	6.4
12	*Alstonia scholaris*	0.5	0.25	2.36	1.55	1.39	2.86	5.8
13	*Cyathocalyx zeylanicus*	0.75	0.5	0.46	2.32	2.78	0.56	5.66
14	*Macaranga peltata*	0.5	0.5	0.96	1.55	2.78	1.16	5.49
15	*Xanthophyllum flavescens*	0.75	0.5	0.2	2.32	2.78	0.24	5.34
16	*Lophopetalum wightianum*	0.5	0.25	1.91	1.55	1.39	2.32	5.26
17	*Cinnamomum malabatrum*	0.5	0.5	0.15	1.55	2.78	0.19	4.51
18	*Aglaia edulis*	0.5	0.5	0.06	1.55	2.78	0.07	4.4
19	*Alseodaphne semecarpifolia*	0.5	0.25	0.92	1.55	1.39	1.12	4.06

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
20	*Bombax ceiba*	0.25	0.25	1.34	0.77	1.39	1.63	3.79
21	*Myristica beddomei*	0.5	0.25	0.13	1.55	1.39	0.16	3.1
22	*Mallotus philippensis*	0.5	0.25	0.12	1.55	1.39	0.15	3.08
23	*Elaeocarpus serratus*	0.5	0.25	0.1	1.55	1.39	0.12	3.06
24	*Prismatomeris tetrandra*	0.5	0.25	0.08	1.55	1.39	0.09	3.03
25	*Symplocos macrophylla*	0.5	0.25	0.02	1.55	1.39	0.03	2.97
26	*Turpinia malabarica*	0.25	0.25	0.51	0.77	1.39	0.62	2.79
27	*Syzygium lanceolatum*	0.25	0.25	0.1	0.77	1.39	0.12	2.28
28	*Machilus macranthus*	0.25	0.25	0.09	0.77	1.39	0.11	2.27
29	*Gymnacranthera farquhariana*	0.25	0.25	0.07	0.77	1.39	0.09	2.25
30	*Carallia brachiata*	0.25	0.25	0.05	0.77	1.39	0.07	2.23
31	*Lagerstroemia microcarpa*	0.25	0.25	0.05	0.77	1.39	0.07	2.23
32	*Otonephelium stipulaceum*	0.25	0.25	0.05	0.77	1.39	0.06	2.22
33	*Calophyllum polyanthum*	0.25	0.25	0.05	0.77	1.39	0.06	2.22
34	*Sterculia guttata*	0.25	0.25	0.04	0.77	1.39	0.05	2.22
35	*Syzygium bourdillonii*	0.25	0.25	0.04	0.77	1.39	0.05	2.22
36	*Lagerstroemia speciosa*	0.25	0.25	0.04	0.77	1.39	0.05	2.21
37	*Ixora brachiata*	0.25	0.25	0.03	0.77	1.39	0.04	2.21
38	*Canarium strictum*	0.25	0.25	0.03	0.77	1.39	0.04	2.2
39	*Garcinia spicata*	0.25	0.25	0.03	0.77	1.39	0.04	2.2
40	*Garcinia gummi-gutta*	0.25	0.25	0.02	0.77	1.39	0.02	2.18
41	*Gmelina arborea*	0.25	0.25	0.02	0.77	1.39	0.02	2.18
42	*Actinodaphne wightiana*	0.25	0.25	0.01	0.77	1.39	0.02	2.18
43	*Mussaenda frondosa*	0.25	0.25	0.01	0.77	1.39	0.01	2.18
44	*Cinnamomum sulphuratum*	0.25	0.25	0.01	0.77	1.39	0.01	2.17
45	*Leea asiatica*	0.25	0.25	0.01	0.77	1.39	0.01	2.17
46	*Memecylon angustifolium*	0.25	0.25	0.01	0.77	1.39	0.01	2.17
47	*Homonoia riparia*	0.25	0.25	0.01	0.77	1.39	0.01	2.17
Total		32.30	18.00	82.30	100	100	100	300

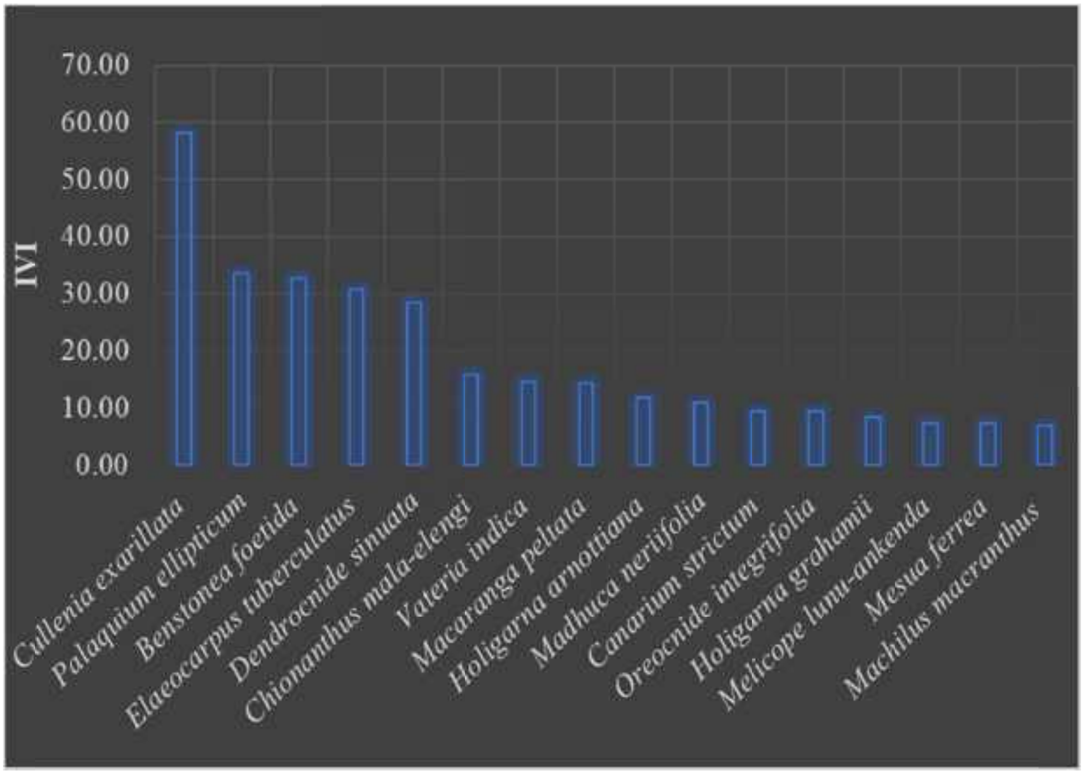
27. **Dominant species associations in Cluster - 9e**



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Diospyros crumenata*	3	1	3.98	11.54	6.45	27.82	45.81
2	*Otonephelium stipulaceum*	2.5	1	1.1	9.62	6.45	7.66	23.73
3	*Monoon fragrans*	2	1	1.11	7.69	6.45	7.78	21.93
4	*Dipterocarpus indicus*	1	1	1.49	3.85	6.45	10.43	20.73
5	*Gymnacranthera farquhariana*	1	1	1.24	3.85	6.45	8.64	18.94
6	*Syzygium cumini*	1	1	1.02	3.85	6.45	7.13	17.43
7	*Glochidion ellipticum*	1.5	0.5	1.13	5.77	3.23	7.87	16.86
8	*Canarium strictum*	1.5	1	0.52	5.77	6.45	3.65	15.87
9	*Schleichera oleosa*	1.5	1	0.49	5.77	6.45	3.45	15.67
10	*Terminalia paniculata*	1	1	0.71	3.85	6.45	4.94	15.24
11	*Cinnamomum sulphuratum*	1.5	1	0.11	5.77	6.45	0.75	12.97
12	*Carallia brachiata*	1	0.5	0.78	3.85	3.23	5.42	12.49
13	*Symplocos cochinchinensis*	2	0.5	0.19	7.69	3.23	1.35	12.27
14	*Symplocos macrophylla*	1.5	0.5	0.04	5.77	3.23	0.26	9.25
15	*Baccaurea courtallensis*	1	0.5	0.05	3.85	3.23	0.34	7.41
16	*Macaranga peltata*	0.5	0.5	0.24	1.92	3.23	1.67	6.81
17	*Litsea coriacea*	0.5	0.5	0.05	1.92	3.23	0.37	5.52

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
18	*Prismatomeris tetrandra*	0.5	0.5	0.03	1.92	3.23	0.24	5.39
19	*Litsea floribunda*	0.5	0.5	0.02	1.92	3.23	0.13	5.28
20	*Mycetia acuminata*	0.5	0.5	0.01	1.92	3.23	0.05	5.2
21	*Homonoia riparia*	0.5	0.5	0.01	1.92	3.23	0.05	5.2
Total		26.00	15.50	14.30	100	100	100	300

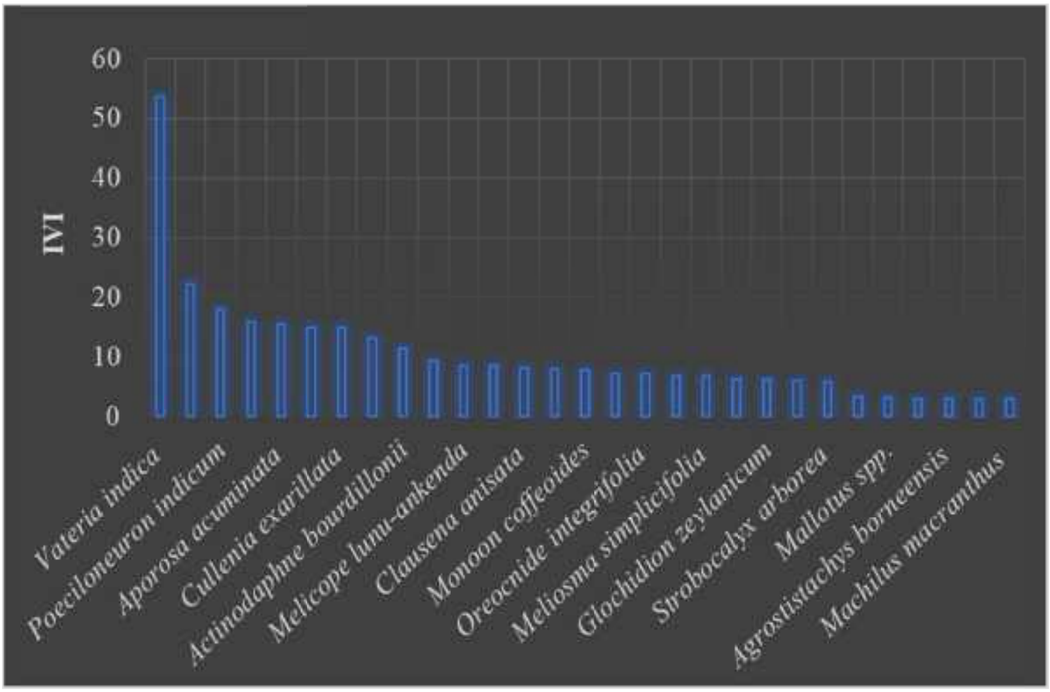
28. **Dominant species associations in Cluster - 9f**



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Cullenia exarillata*	2.5	1	3.89	11.11	9.09	37.94	58.14
2	*Palaquium ellipticum*	1	1	2.06	4.44	9.09	20.12	33.65
3	*Benstonea foetida*	5	1	0.14	22.22	9.09	1.39	32.71
4	*Elaeocarpus tuberculatus*	1.5	1	1.54	6.67	9.09	15.03	30.79
5	*Dendrocnide sinuata*	3.5	1	0.39	15.56	9.09	3.79	28.44
6	*Chionanthus mala-elengi*	1	1	0.23	4.44	9.09	2.27	15.81
7	*Vateria indica*	1	0.5	0.57	4.44	4.55	5.58	14.57
8	*Macaranga peltata*	1.5	0.5	0.33	6.67	4.55	3.23	14.44

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
9	*Holigarna arnottiana*	1	0.5	0.28	4.44	4.55	2.77	11.76
10	*Madhuca neriifolia*	1	0.5	0.19	4.44	4.55	1.89	10.88
11	*Canarium strictum*	0.5	0.5	0.28	2.22	4.55	2.74	9.51
12	*Oreocnide integrifolia*	1	0.5	0.05	4.44	4.55	0.46	9.45
13	*Holigarna grahamii*	0.5	0.5	0.17	2.22	4.55	1.66	8.42
14	*Melicope lunu-ankenda*	0.5	0.5	0.06	2.22	4.55	0.56	7.33
15	*Mesua ferrea*	0.5	0.5	0.05	2.22	4.55	0.46	7.23
16	*Machilus macranthus*	0.5	0.5	0.01	2.22	4.55	0.09	6.86
Total		22.50	11.00	10.25	100	100	100	300

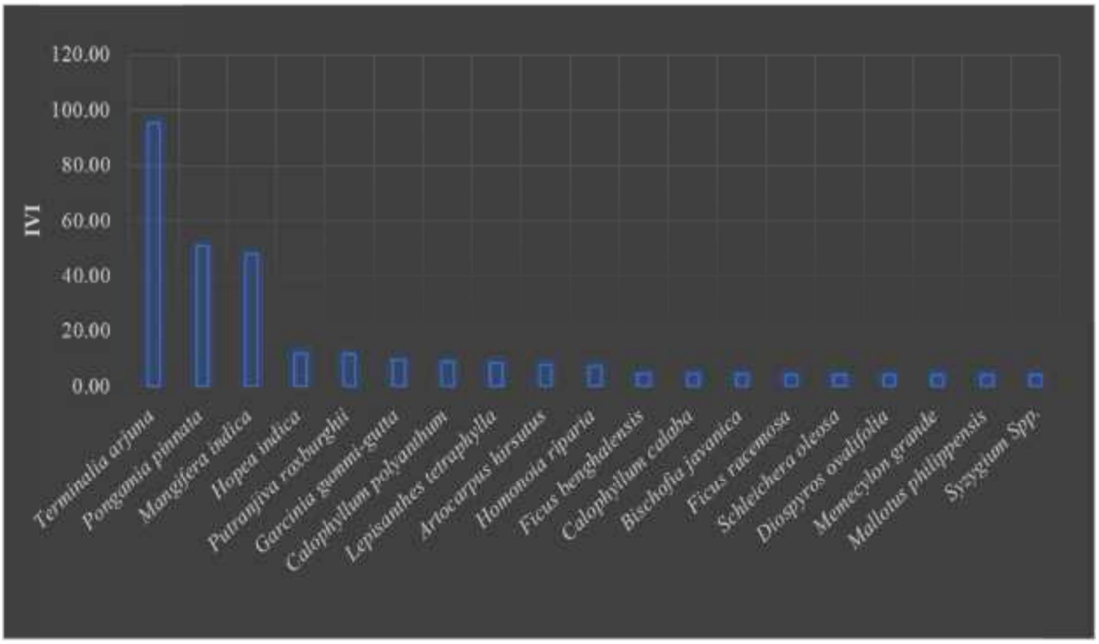
29. Dominant species associations in Cluster - 9g



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Vateria indica*	2.33	1.00	9.32	7.07	5.36	41.24	53.67
2	*Schleichera oleosa*	3.67	1.00	1.31	11.11	5.36	5.81	22.27
3	*Poeciloneuron indicum*	1.33	1.00	1.95	4.04	5.36	8.63	18.03
4	*Cinnamomum cassia*	2	1.00	1	6.06	5.36	4.41	15.83
5	*Aporosa acuminata*	3.67	0.67	0.17	11.11	3.57	0.76	15.44
6	*Callicarpa tomentosa*	2	1.00	0.81	6.06	5.36	3.56	14.98

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
7	*Cullenia exarillata*	1.33	0.67	1.63	4.04	3.57	7.2	14.81
8	*Elaeocarpus tuberculatus*	1	1.00	1.07	3.03	5.36	4.74	13.13
9	*Actinodaphne bourdillonii*	2	0.67	0.4	6.06	3.57	1.75	11.38
10	*Aglaia lawii*	1	0.67	0.59	3.03	3.57	2.63	9.23
11	*Melicope lunu-ankenda*	1	0.67	0.43	3.03	3.57	1.91	8.51
12	*Ficus talbotii*	0.33	0.33	1.27	1.01	1.79	5.64	8.43
13	*Clausena anisata*	1.33	0.67	0.12	4.04	3.57	0.52	8.14
14	*Macaranga peltata*	0.67	0.67	0.53	2.02	3.57	2.36	7.95
15	*Monoon coffeoides*	1	0.67	0.26	3.03	3.57	1.15	7.76
16	*Alstonia scholaris*	0.67	0.67	0.36	2.02	3.57	1.6	7.19
17	*Oreocnide integrifolia*	1	0.67	0.13	3.03	3.57	0.58	7.18
18	*Clerodendrum infortunatum*	1	0.67	0.04	3.03	3.57	0.19	6.79
19	*Meliosma simplicifolia*	0.67	0.67	0.26	2.02	3.57	1.13	6.72
20	*Spondias pinnata*	0.67	0.67	0.16	2.02	3.57	0.71	6.3
21	*Glochidion zeylanicum var. zeylanicum*	0.67	0.67	0.13	2.02	3.57	0.58	6.17
22	*Alseodaphne semecarpifolia*	1	0.33	0.29	3.03	1.79	1.27	6.09
23	*Strobocalyx arborea*	0.67	0.67	0.05	2.02	3.57	0.24	5.83
24	*Myristica beddomei*	0.33	0.33	0.13	1.01	1.79	0.56	3.36
25	*Mallotus spp.*	0.33	0.33	0.09	1.01	1.79	0.42	3.21
26	*Hydnocarpus alpina*	0.33	0.33	0.03	1.01	1.79	0.14	2.93
27	*Agrostistachys borneensis*	0.33	0.33	0.03	1.01	1.79	0.13	2.92
28	*Antidesma montanum*	0.33	0.33	0.02	1.01	1.79	0.07	2.86
29	*Machilus macranthus*	0.33	0.33	0.02	1.01	1.79	0.07	2.86
Total		33	18.66	22.6	100	100	100	300

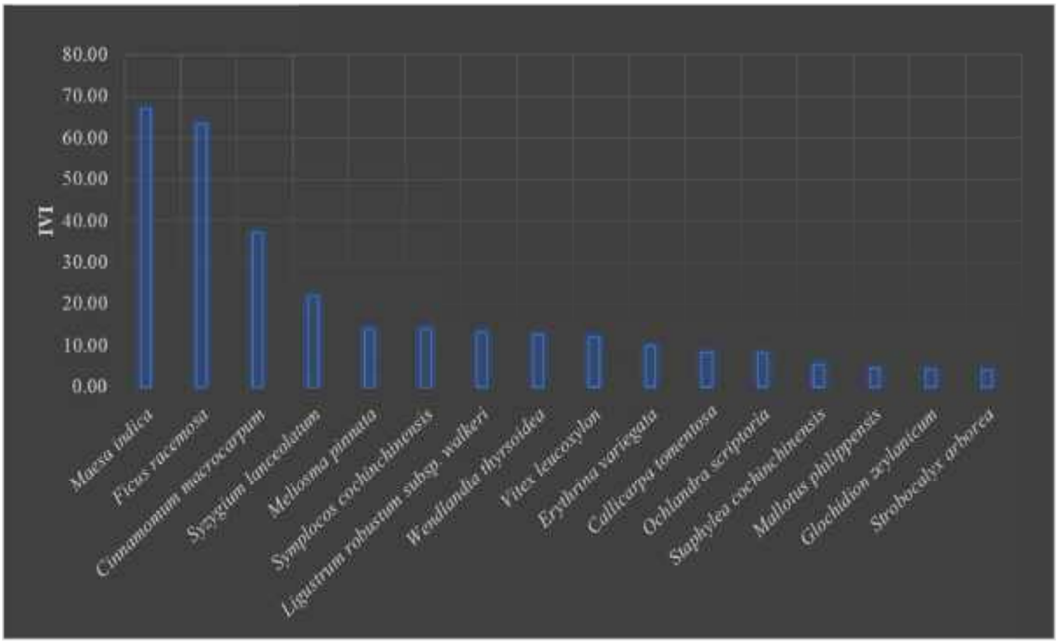
30. Dominant species associations in Cluster – 10



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Terminalia arjuna*	2	1	60.7	18.18	16.67	60.55	95.39
2	*Pongamia pinnata*	2.5	0.83	14.1	22.73	13.89	14.1	50.72
3	*Mangifera indica*	1.67	0.83	19.2	15.15	13.89	19.12	48.16
4	*Hopea indica*	0.5	0.33	2.14	4.55	5.56	2.14	12.24
5	*Putranjiva roxburghii*	0.67	0.33	0.21	6.06	5.56	0.21	11.82
6	*Garcinia gummi-gutta*	0.33	0.33	1.04	3.03	5.56	1.04	9.63
7	*Calophyllum polyanthum*	0.5	0.17	1.58	4.55	2.78	1.58	8.9
8	*Lepisanthes tetraphylla*	0.33	0.33	0.11	3.03	5.56	0.11	8.7
9	*Artocarpus hirsutus*	0.5	0.17	0.62	4.55	2.78	0.61	7.94
10	*Homonoia riparia*	0.5	0.17	0.08	4.55	2.78	0.08	7.4
11	*Ficus benghalensis*	0.17	0.17	0.15	1.52	2.78	0.14	4.44
12	*Calophyllum calaba*	0.17	0.17	0.12	1.52	2.78	0.12	4.42
13	*Bischofia javanica*	0.17	0.17	0.11	1.52	2.78	0.11	4.4
14	*Ficus racemosa*	0.17	0.17	0.02	1.52	2.78	0.02	4.31
15	*Schleichera oleosa*	0.17	0.17	0.02	1.52	2.78	0.02	4.31
16	*Diospyros ovalifolia*	0.17	0.17	0.01	1.52	2.78	0.01	4.31
17	*Memecylon grande*	0.17	0.17	0.01	1.52	2.78	0.01	4.3

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
18	*Mallotus philippensis*	0.17	0.17	0.01	1.52	2.78	0.01	4.3
19	*Syzygium Spp.*	0.17	0.17	0.01	1.52	2.78	0.01	4.3
Total		11	6.00	100.17	100	100	100	300

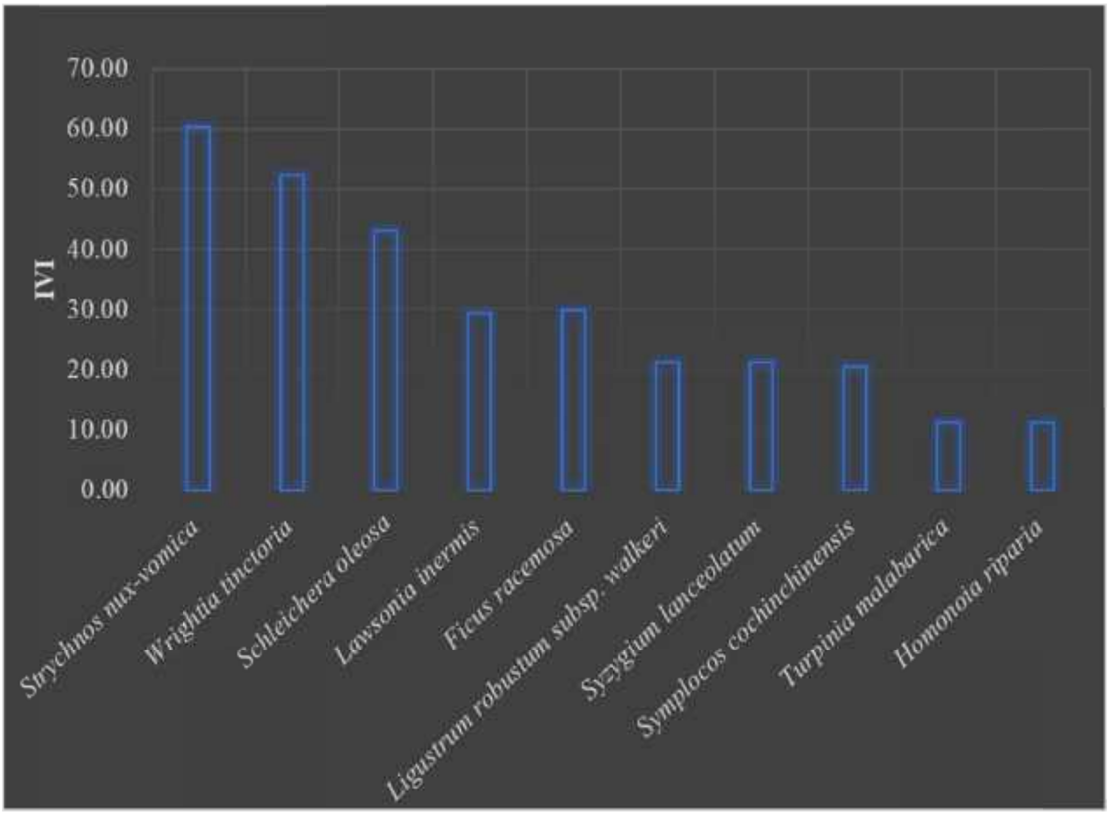
31. Dominant species associations in Cluster - 11a



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Maesa indica*	10	1	0.6	49.5	15.15	2.47	67.13
2	*Ficus racemosa*	0.6	0.6	12	2.97	9.09	51.23	63.29
3	*Cinnamomum macrocarpum*	1.4	0.6	5	6.93	9.09	21.04	37.06
4	*Syzygium lanceolatum*	1.2	0.4	2.4	5.94	6.06	9.91	21.91
5	*Meliosma pinnata*	0.6	0.4	1.2	2.97	6.06	5	14.03
7	*Symplocos cochinchinensis*	1	0.4	0.7	4.95	6.06	2.92	13.93
8	*Ligustrum robustum subsp. walkeri*	0.6	0.6	0.3	2.97	9.09	1.22	13.28
9	*Wendlandia thyrsoidea*	1	0.4	0.4	4.95	6.06	1.51	12.53
10	*Vitex leucoxylon*	1	0.4	0.3	4.95	6.06	1.07	12.08
11	*Erythrina variegata*	0.4	0.4	0.5	1.98	6.06	1.89	9.93
12	*Callicarpa tomentosa*	0.4	0.4	0.1	1.98	6.06	0.29	8.34
13	*Ochlandra scriptoria*	1	0.2	0.1	4.95	3.03	0.21	8.19

Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
14	*Staphylea cochinchinensis*	0.4	0.2	0.1	1.98	3.03	0.44	5.45
15	*Mallotus philippensis*	0.2	0.2	0.1	0.99	3.03	0.48	4.5
16	*Glochidion zeylanicum var. zeylanicum*	0.2	0.2	0.1	0.99	3.03	0.21	4.23
17	*Strobocalyx arborea*	0.2	0.2	0	0.99	3.03	0.12	4.14
Total		20.2	6.6	24	100	100	100	300

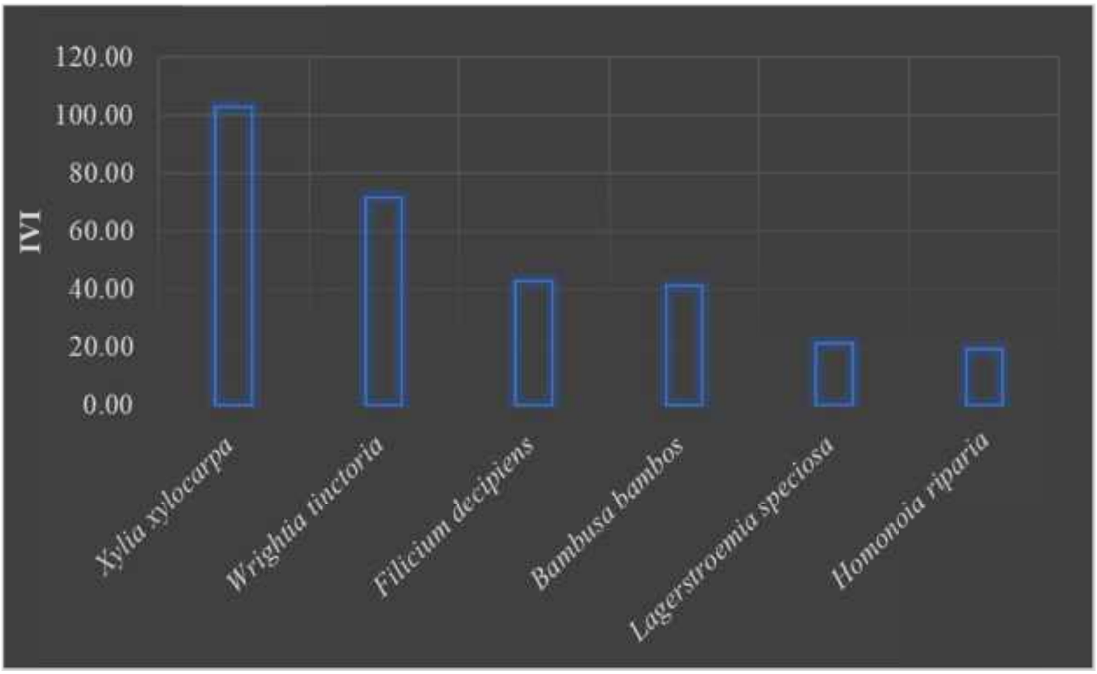
32. Dominant species associations in Cluster - 11b



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Strychnos nux-vomica*	2	1	0.76	12.5	15.38	32.48	60.37
2	*Wrightia tinctoria*	4	0.5	0.46	25	7.69	19.59	52.29
3	*Schleichera oleosa*	2.5	1	0.28	15.63	15.38	12.02	43.03
4	*Lawsonia inermis*	1.5	1	0.11	9.38	15.38	4.58	29.34
5	*Ficus racemosa*	1	0.5	0.37	6.25	7.69	15.87	29.81
7	*Ligustrum robustum subsp. walkeri*	1	0.5	0.17	6.25	7.69	7.25	21.19
8	*Syzygium lanceolatum*	1	0.5	0.17	6.25	7.69	7.15	21.09

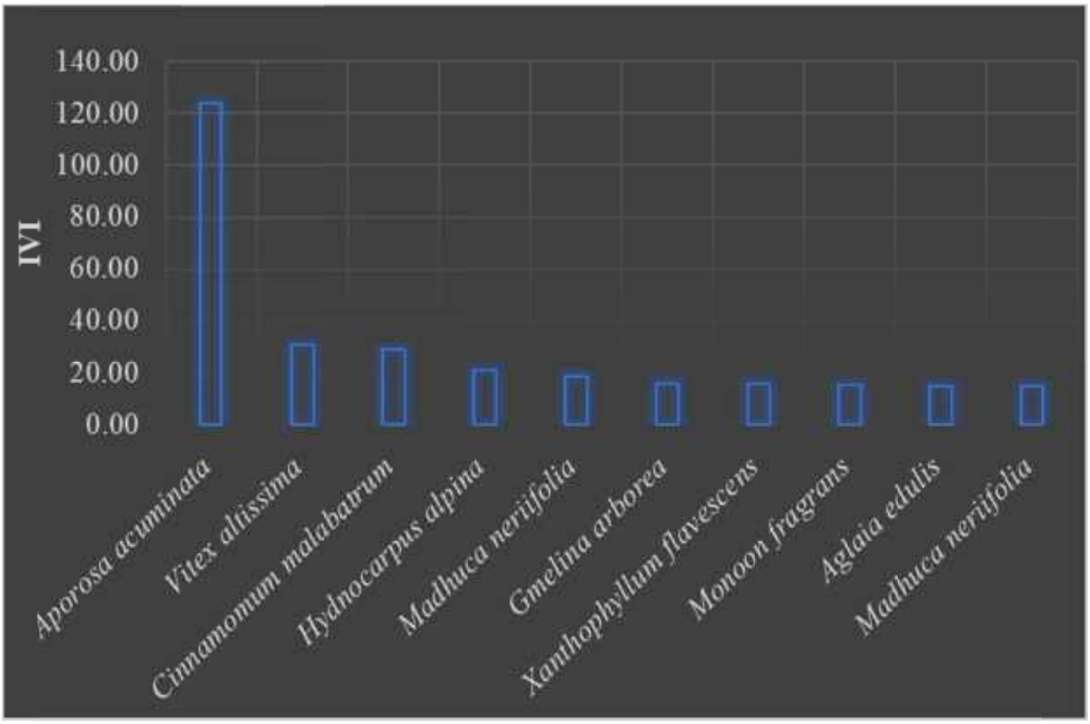
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
9	*Symplocos cochinchinensis*	2	0.5	0.01	12.5	7.69	0.35	20.54
10	*Turpinia malabarica*	0.5	0.5	0.01	3.13	7.69	0.39	11.21
11	*Homonoia riparia*	0.5	0.5	0.01	3.13	7.69	0.31	11.12
Total		16.00	6.50	2.34	100	100	100	300

33. Dominant species associations in Cluster - O1



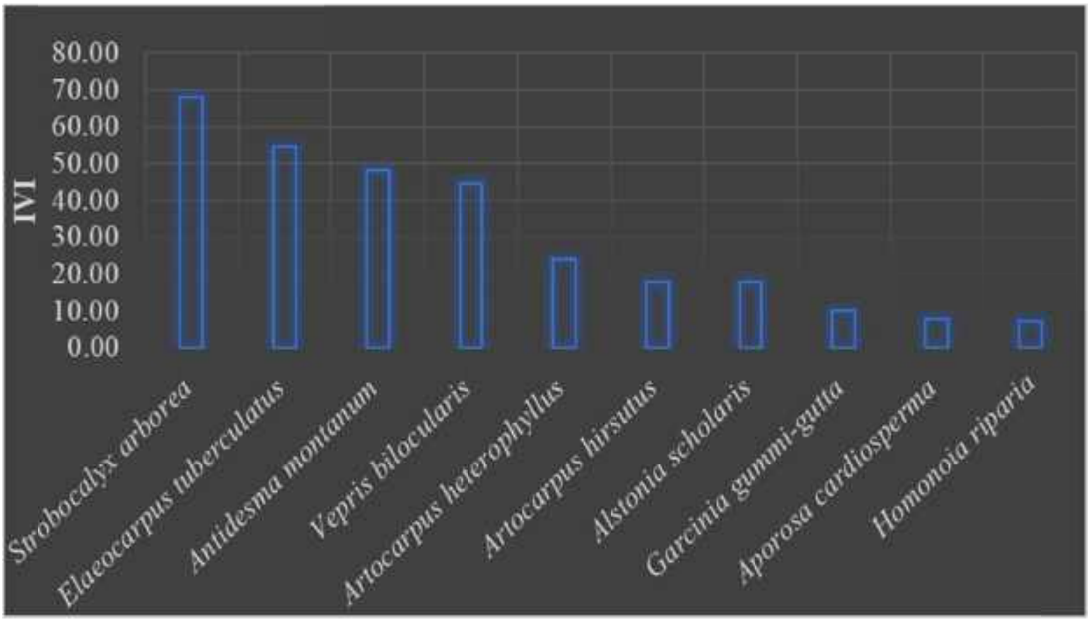
Sl No.	Name of Species	D	F	BA (m2)	RD	RF	RBA	IVI
1	*Xylia xylocarpa*	1.00	1.00	1.56	18.18	20.00	64.78	102.96
2	*Wrightia tinctoria*	1.50	1.00	0.59	27.27	20.00	24.53	71.81
3	*Filicium decipiens*	1.00	1.00	0.11	18.18	20.00	4.62	42.80
4	*Bambusa bambos*	1.00	1.00	0.08	18.18	20.00	3.32	41.50
5	*Lagerstroemia speciosa*	0.50	0.50	0.06	9.09	10.00	2.45	21.54
6	*Homonoia riparia*	0.50	0.50	0.01	9.09	10.00	0.30	19.39
Total		5.50	5.00	2.40	100	100	100	300

34. Dominant species associations in Cluster - O2



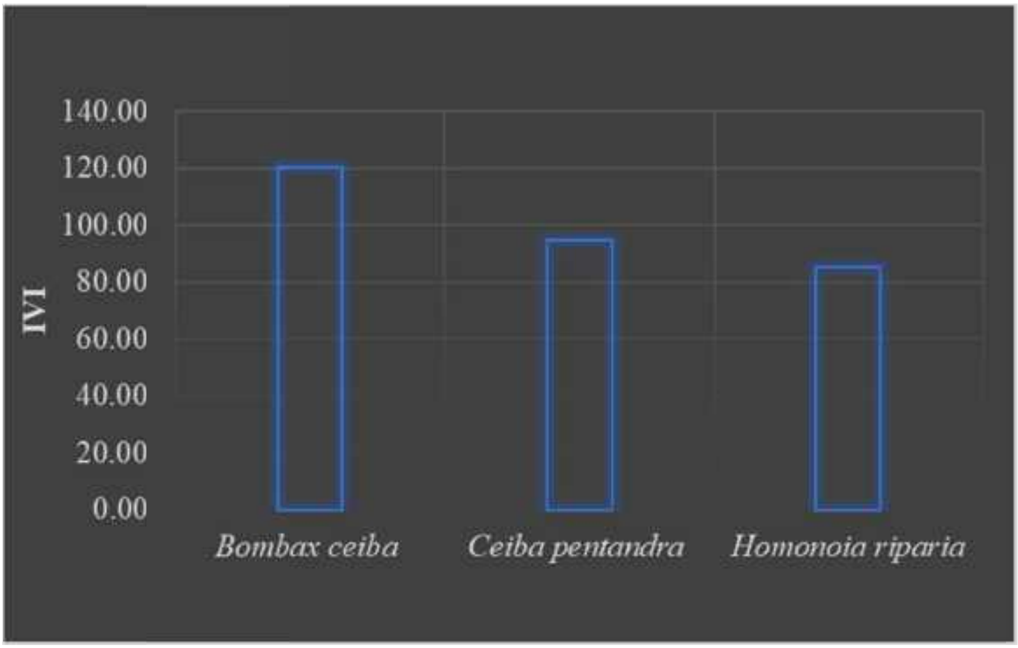
Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Aporosa acuminata*	3.5	1	1.3	38.9	18.18	66.73	123.8
2	*Vitex altissima*	0.5	0.5	0.3	5.56	9.09	16.18	30.83
3	*Cinnamomum malabatrum*	1	0.5	0.2	11.1	9.09	8.98	29.18
4	*Hydnocarpus alpina*	1	0.5	0	11.1	9.09	0.97	21.17
5	*Madhuca neriifolia*	0.5	0.5	0.1	5.56	9.09	3.8	18.45
6	*Gmelina arborea*	0.5	0.5	0	5.56	9.09	1.05	15.7
7	*Xanthophyllum flavescens*	0.5	0.5	0	5.56	9.09	1.01	15.66
8	*Monoon fragrans*	0.5	0.5	0	5.56	9.09	0.49	15.13
9	*Aglaia edulis*	0.5	0.5	0	5.56	9.09	0.4	15.05
10	*Madhuca neriifolia*	0.5	0.5	0	5.56	9.09	0.38	15.03
Total		9	5.5	1.9	100	100	100	300

35. Dominant species associations in Cluster - O3



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Strobocalyx arborea*	4	**1**	5.07	27.27	14.29	26.53	68.09
2	*Elaeocarpus tuberculatus*	1.67	1.00	5.52	11.36	14.29	28.91	54.56
3	*Antidesma montanum*	3.67	1.00	1.72	25	14.29	9.01	48.29
4	*Vepris bilocularis*	1.67	1.00	3.6	11.36	14.29	18.82	44.46
5	*Artocarpus heterophyllus*	1	0.67	1.44	6.82	9.52	7.56	23.9
7	*Artocarpus hirsutus*	0.67	0.67	0.75	4.55	9.52	3.9	17.97
8	*Alstonia scholaris*	0.67	0.67	0.72	4.55	9.52	3.75	17.82
9	*Garcinia gummi-gutta*	0.67	0.33	0.16	4.55	4.76	0.84	10.15
10	*Aporosa cardiosperma*	0.33	0.33	0.12	2.27	4.76	0.64	7.68
11	*Homonoia riparia*	0.33	0.33	0.01	2.27	4.76	0.04	7.07
Total		14.66	7	19.1	100	100	100	300

36. Dominant species associations in Cluster - O4



Sl No.	Name of Species	D	F	BA (m^2)	RD	RF	RBA	IVI
1	*Bombax ceiba*	1	1	0.19	28.57	33.33	58.3	120.2
2	*Ceiba pentandra*	1	1	0.11	28.57	33.33	32.79	94.7
3	*Homonoia riparia*	1.5	1	0.03	42.86	33.33	8.91	85.1
Total		3.50	3.00	0.33	100	100	100	300

*Density (D), Frequency (F), Basal area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal area (RBA) and Importance Value Index (IVI)

APPENDIX - V

Linear r (Pearson) correlation between identified clusters of the Anamalai landscape

	Cluster 1a	Cluster 1b	Cluster 1c	Cluster 1d	Cluster 2a	Cluster 2b	Cluster 3a	Cluster 3b	Cluster 4a	Cluster 4b	Cluster 5a
Cluster 1a	*	0.56	0.30	0.34	0.10	0.28	0.52	0.29	0.35	0.13	-0.03
Cluster 1b	*	*	0.43	0.39	0.13	0.10	0.03	-0.02	0.00	-0.02	0.11
Cluster 1c	*	*	*	0.18	-0.01	-0.02	-0.03	-0.03	0.08	-0.02	-0.02
Cluster 1d	*	*	*	*	0.01	0.14	0.03	0.04	-0.02	-0.03	-0.03
Cluster 2a	*	*	*	*	*	0.32	-0.02	-0.02	-0.02	-0.01	-0.01
Cluster 2b	*	*	*	*	*	*	0.20	0.14	0.04	-0.02	-0.02
Cluster 3a	*	*	*	*	*	*	*	0.52	0.39	0.13	0.23
Cluster 3b	*	*	*	*	*	*	*	*	0.00	-0.02	-0.03
Cluster 4a	*	*	*	*	*	*	*	*	*	0.32	0.06
Cluster 4b	*	*	*	*	*	*	*	*	*	*	-0.02
Cluster 5a	*	*	*	*	*	*	*	*	*	*	*
Cluster 5b	*	*	*	*	*	*	*	*	*	*	*
Cluster 6a	*	*	*	*	*	*	*	*	*	*	*

Cluster 6b	*	*	*	*	*	*	*	*	*	*	*
Cluster 6c	*	*	*	*	*	*	*	*	*	*	*
Cluster 6d	*	*	*	*	*	*	*	*	*	*	*
Cluster 6e	*	*	*	*	*	*	*	*	*	*	*
Cluster 7a	*	*	*	*	*	*	*	*	*	*	*
Cluster 7b	*	*	*	*	*	*	*	*	*	*	*
Cluster 7c	*	*	*	*	*	*	*	*	*	*	*
Cluster 8a	*	*	*	*	*	*	*	*	*	*	*
Cluster 8b	*	*	*	*	*	*	*	*	*	*	*
Cluster 9a	*	*	*	*	*	*	*	*	*	*	*
Cluster 9b	*	*	*	*	*	*	*	*	*	*	*
Cluster 9c	*	*	*	*	*	*	*	*	*	*	*
Cluster 9d	*	*	*	*	*	*	*	*	*	*	*
Cluster 9e	*	*	*	*	*	*	*	*	*	*	*
Cluster 9f	*	*	*	*	*	*	*	*	*	*	*
Cluster 9g	*	*	*	*	*	*	*	*	*	*	*

Cluster 10	*	*	*	*	*	*	*	*	*	*	*
Cluster 11a	*	*	*	*	*	*	*	*	*	*	*
Cluster 11b	*	*	*	*	*	*	*	*	*	*	*
Cluster O1	*	*	*	*	*	*	*	*	*	*	*
Cluster O2	*	*	*	*	*	*	*	*	*	*	*
Cluster O3	*	*	*	*	*	*	*	*	*	*	*
Cluster O4	*	*	*	*	*	*	*	*	*	*	*

Cluster 5b	**Cluster 6a**	**Cluster 6b**	**Cluster 6c**	**Cluster 6d**	**Cluster 6e**	**Cluster 7a**	**Cluster 7b**	**Cluster 7c**	**Cluster 8a**	**Cluster 8b**	**Cluster 9a**
0.04	0.00	-0.02	-0.01	-0.03	-0.03	0.00	-0.03	-0.02	-0.02	-0.01	-0.02
0.10	0.01	0.07	0.00	0.02	-0.03	0.01	-0.02	-0.01	-0.02	0.01	-0.03
-0.03	0.10	-0.03	0.04	-0.05	0.02	0.00	-0.03	-0.01	-0.02	0.00	-0.03
-0.03	0.03	0.02	0.00	0.07	-0.02	0.00	0.07	0.05	0.00	0.00	0.07
-0.02	-0.01	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02	-0.01	-0.01	-0.01	-0.02
0.07	0.00	0.12	0.01	0.21	-0.03	0.00	-0.02	-0.01	-0.02	-0.01	-0.03
0.07	0.03	0.05	0.01	0.07	-0.03	0.00	-0.02	-0.01	-0.02	-0.01	-0.04

-0.03	-0.04	0.02	-0.02	0.03	-0.04	-0.02	-0.03	-0.01	-0.02	-0.02	-0.03
0.00	0.05	0.00	0.00	-0.03	-0.01	-0.01	-0.03	-0.01	-0.02	-0.01	-0.02
-0.03	-0.03	-0.03	-0.03	-0.04	-0.03	-0.01	-0.02	-0.01	-0.02	-0.01	-0.03
0.23	0.22	-0.05	-0.01	-0.05	-0.02	0.02	0.00	-0.01	-0.02	-0.02	-0.03
*	0.03	0.03	-0.03	-0.03	-0.05	0.02	-0.02	-0.01	-0.02	-0.02	-0.03
*	*	0.21	0.12	0.09	0.21	0.05	0.77	0.83	0.08	0.14	-0.02
*	*	*	0.50	0.37	0.19	0.01	0.22	0.16	-0.03	-0.01	0.02
*	*	*	*	0.38	0.50	0.05	0.31	0.09	-0.01	0.01	-0.03
*	*	*	*	*	0.29	0.02	0.30	0.13	0.04	-0.01	0.12
*	*	*	*	*	*	0.36	0.42	0.25	-0.02	-0.02	0.13
*	*	*	*	*	*	*	0.10	0.17	-0.01	-0.01	0.00
*	*	*	*	*	*	*	*	0.90	0.11	0.13	0.06
*	*	*	*	*	*	*	*	*	0.00	-0.01	-0.01
*	*	*	*	*	*	*	*	*	*	0.66	0.02
*	*	*	*	*	*	*	*	*	*	*	-0.02
*	*	*	*	*	*	*	*	*	*	*	*

*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*

Cluster 9b	Cluster 9c	Cluster 9d	Cluster 9e	Cluster 9f	Cluster 9g	Cluster 10	Cluster 11a	Cluster 11b	Cluster O1	Cluster O2	Cluster O3	Cluster O4
-0.04	-0.05	-0.03	-0.06	-0.04	-0.06	-0.02	-0.02	-0.04	0.09	0.01	-0.03	-0.02
-0.03	-0.02	0.02	-0.03	0.00	-0.02	-0.03	-0.02	-0.02	0.18	0.02	-0.01	-0.01
-0.04	0.00	-0.02	-0.05	-0.03	-0.03	0.03	-0.02	-0.03	0.08	-0.02	-0.03	-0.02
0.01	0.12	0.12	-0.02	0.01	0.00	0.00	-0.01	-0.04	0.06	0.00	-0.03	0.00
-0.02	-0.03	-0.03	-0.03	-0.02	-0.03	-0.02	-0.01	-0.02	-0.01	-0.01	-0.02	-0.01
-0.03	0.01	-0.02	-0.04	0.05	-0.03	-0.03	-0.02	-0.02	-0.02	0.03	-0.02	-0.01
0.00	-0.01	-0.02	-0.03	0.08	-0.03	-0.04	-0.02	-0.03	-0.03	0.03	-0.03	0.05
-0.04	-0.02	-0.06	0.00	0.00	-0.05	0.02	-0.02	-0.03	-0.03	-0.03	0.10	-0.02
-0.03	-0.04	-0.01	-0.01	0.04	0.05	0.00	-0.02	0.01	-0.03	-0.03	0.04	-0.02
-0.03	-0.04	-0.05	-0.04	-0.03	-0.04	-0.03	-0.02	-0.03	-0.02	-0.02	-0.02	-0.01
-0.03	0.03	0.01	0.06	0.14	0.03	-0.03	-0.02	0.22	0.21	-0.02	-0.03	-0.02
-0.04	-0.03	-0.03	-0.02	0.01	-0.02	0.13	0.01	-0.02	-0.03	0.00	-0.03	-0.02
0.05	-0.03	-0.01	-0.03	0.00	-0.01	0.04	0.05	-0.03	-0.04	0.01	0.05	0.00
-0.02	-0.04	0.05	0.02	-0.03	0.03	-0.04	-0.03	0.02	-0.04	0.04	-0.02	-0.03
0.34	0.00	0.00	-0.04	-0.03	-0.05	-0.02	-0.02	-0.04	-0.01	0.00	-0.04	-0.02
0.21	0.19	0.20	0.03	0.07	0.05	-0.03	-0.03	-0.06	-0.02	0.06	-0.05	0.07
0.01	-0.03	-0.05	-0.06	0.00	-0.05	-0.03	0.00	-0.01	0.11	0.01	-0.03	0.06
0.04	-0.03	-0.04	-0.03	-0.01	-0.03	-0.02	-0.01	-0.02	0.42	-0.01	-0.02	-0.01
0.13	0.06	0.04	-0.04	0.02	0.02	-0.03	0.07	-0.02	-0.01	-0.01	-0.03	-0.01
-0.02	-0.02	-0.03	-0.03	-0.02	-0.03	-0.02	0.09	-0.02	0.04	-0.01	-0.01	-0.01

0.28	0.06	0.03	-0.02	0.00	0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	-0.01
0.42	-0.01	0.00	-0.02	-0.02	-0.01	-0.02	-0.01	-0.01	-0.01	0.00	-0.01	-0.01
0.06	-0.04	0.02	-0.03	0.12	0.11	0.00	-0.03	0.02	-0.03	0.07	-0.02	-0.02
*	0.03	0.06	0.02	0.00	0.06	0.04	-0.03	0.00	-0.04	0.06	-0.03	-0.02
*	*	0.21	0.05	0.16	0.19	-0.05	-0.04	-0.05	-0.04	0.00	-0.05	0.03
*	*	*	0.24	0.00	0.21	-0.05	-0.04	0.08	-0.05	0.07	-0.05	-0.01
*	*	*	*	-0.03	0.04	-0.05	-0.01	0.16	-0.04	0.00	-0.05	-0.03
*	*	*	*	*	0.11	-0.05	-0.03	-0.04	-0.03	-0.02	0.02	-0.02
*	*	*	*	*	*	-0.04	-0.03	0.15	-0.05	0.41	0.08	-0.03
*	*	*	*	*	*	*	-0.02	-0.01	-0.03	-0.03	-0.01	-0.02
*	*	*	*	*	*	*	*	0.05	-0.02	-0.02	-0.01	-0.01
*	*	*	*	*	*	*	*	*	0.41	-0.03	-0.03	-0.02
*	*	*	*	*	*	*	*	*	*	-0.02	-0.03	-0.02
*	*	*	*	*	*	*	*	*	*	*	-0.03	-0.02
*	*	*	*	*	*	*	*	*	*	*	*	-0.02
*	*	*	*	*	*	*	*	*	*	*	*	*

APPENDIX - VI

List of tree species recorded in the riparian forest enumeration of the Anamalai landscape

Sl. No	Species Name	Common Name	Family
1	*Acrocarpus fraxinifolius* Wight & Arn.	Narivenga	Fabaceae
2	*Actinodaphne wightiana* (Kuntze) Noltie	Kambilivirinji, Eeyoli	Lauraceae
3	*Actinodaphne bourdillonii* Gamble	Malavirinji	Lauraceae
4	*Aglaia edulis* (Roxb.) Wall.	Chuvanna Akil	Meliaceae
5	*Aglaia lawii* (Wight) C.J.Saldanha	Karagil	Meliaceae
6	*Aglaia perviridis* Hiern	Karakil	Meliaceae
7	*Agrostistachys borneensis* Becc.	Kozhivalan	Euphorbiaceae
8	*Ailanthus triphysa* (Dennst.) Alston	Matti, Mattipala	Simaroubaceae
9	*Alangium salviifolium* (L.f.) Wangerin	Ankolam/Valli-Angolam	Alangiaceae
10	*Albizia lebbeck* (L.) Benth.	Vaka	Fabaceae
11	*Albizia odoratissima* (L.f.) Benth.	Pulivaka	Fabaceae
12	*Allophylus cobbe* (L.) Forsyth f.	Mukkannanpezhu	Sapindaceae
13	*Alseodaphne semecarpifolia* Nees	Cheenthali	Lauraceae
14	*Alstonia scholaris* (L.) R. Br.	Ezhilampala	Apocynaceae
15	*Antidesma montanum* Blume	Puliyarajan	Euphorbiaceae
16	*Aporosa acuminata* Thwaites	Kallidala, Neervetti	Euphorbiaceae
17	*Aporosa bourdillonii* Stapf	Malamvetti	Euphorbiaceae
18	*Aporosa cardiosperma* (Gaertn.) Merr.	Vetti	Euphorbiaceae
19	*Arenga wightii* Griff.	Kattuthengu	Arecaceae
20	*Artocarpus heterophyllus* Lam.	Plavu	Moraceae
21	*Artocarpus hirsutus* Lam.	Anjily, Ayini	Moraceae
22	*Atalantia racemosa* Wight ex Hook.	Kattu Narakam	Rutaceae
23	*Atuna travancorica* (Bedd.) Kosterm.	Kallankaimaram	Chrysobalanaceae
24	*Baccaurea courtallensis* (Wight) Müll.Arg.	Muttilpazham, Uvathan	Euphorbiaceae

Sl. No	Species Name	Common Name	Family
25	*Bambusa bambos* (L.) Voss	Mula	Poaceae
26	*Barringtonia acutangula* (L.) Gaertn.	Attuvanchimaram, Neerpezhu	Lecythidaceae
27	*Bauhinia acuminata* L.	Veluthamandaram, Mantharam	Fabaceae
28	*Bauhinia variegata* L.	Chuvannamandaram, Mandaram	Fabaceae
29	*Bhesa indica* (Bedd.) Ding Hou	Penali	Celastraceae
30	*Bischofia javanica* Blume	Cholavenga	Euphorbiaceae
31	*Bombax ceiba* L.	Elavu	Bombacaceae
32	*Briedelia retusa* (L.) A. Juss.	Mulluvenga	Euphorbiaceae
33	*Buchanania lanzan* Spreng.	Kulamavu	Anacardiaceae
34	*Callicarpa tomentosa* (L.) L.	Cheruthekku	Lamiaceae
35	*Calophyllum austroindicum* Kosterm. ex P.F.Stevens	Kattupunna, Aattupunna	Clusiaceae
36	*Calophyllum calaba* L.	Aattupunna, Cherupunna	Clusiaceae
37	*Calophyllum polyanthum* Wall. ex Choisy	Punna	Clusiaceae
38	*Canarium strictum* Roxb.	Thelli	Burseraceae
39	*Capparis rheedei* DC.	Kakkamullu	Capparaceae
40	*Carallia brachiata* (Lour.) Merr.	Kara-Kandal	Rhizophoraceae
41	*Caryota urens* L.	Anapana, Choondapana	Arecaceae
42	*Cassia fistula* L.	Kanikonna	Fabaceae
43	*Ceiba pentandra* (L.) Gaertn.	Panji	Bombacaceae
44	*Chionanthus mala-elengi* (Dennst.) P.S. Green subsp. *mala-elengi*	Kallidala, Mala-Elengi, Kallelanji	Oleaceae
45	*Chukrasia tabularis* A.Juss.	Chuvannakil, Chandanavemb	Meliaceae
46	*Cinnamomum macrocarpum* Hook.f.	Karuva	Lauraceae
47	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Vayana, Patta	Lauraceae
48	*Cinnamomum riparium* Gamble	Aattuvayana	Lauraceae
49	*Cinnamomum sulphuratum* Nees	Kattukaruva, Edana	Lauraceae
50	*Clausena anisata* (Willd.) Hook.f. ex	Kattukariveppila	Rutaceae

Sl. No	Species Name	Common Name	Family
	Benth.		
51	*Clerodendrum infortunatum* L.	Peru	Lamiaceae
52	*Crateva magna* (Lour.) DC.	Neer-Mathalam	Capparaceae
53	*Cullenia exarillata* A.Robyns	Vediplavu	Bombacaceae
54	*Cyathocalyx zeylanicus* Champ. ex Hook. f. & Thomson	Kudavazha	Annonaceae
55	*Dalbergia lanceolaria* L.f. ssp. *lanceolaria*	Veeti	Fabaceae
56	*Dalbergia latifolia* Roxb.	Cholaveetti	Fabaceae
57	*Datura stramonium* L.	Ummam	Solanaceae
58	*Debregeasia longifolia* (Burm.f.) Wedd.	Neeranji	Urticaceae
59	*Dendrocnide sinuata* (Blume) Chew	Aananakki, Aanathondi	Urticaceae
60	*Dillenia pentagyna* Roxb.	Vazhapunna	Dilleniaceae
61	*Dimocarpus longan* Lour.	Chempoovam, Pasakotta	Sapindaceae
62	*Diospyros montana* Roxb.	Manjakara, Nanchimaram	Ebenaceae
63	*Diospyros ebenum* J.Koenig	Nanchimaram, Karimthali	Ebenaceae
64	*Diospyros buxifolia* (Blume) Hiern	Malamuringa	Ebenaceae
65	*Diospyros candolleana* Wight	Karimaram	Ebenaceae
66	*Diospyros crumenata* Thwaites	Karimbudan, Karimbudal	Ebenaceae
67	*Syzygium mundagam* (Bourd.) Chithra	Kattuchamba	Myrtaceae
68	*Diospyros ovalifolia* Wight	Karimaram, Karimpala	Ebenaceae
69	*Diospyros paniculata* Dalzell	Karivela, Karivellala	Ebenaceae
70	*Diospyros sylvatica* Roxb.	Karimaram	Ebenaceae
71	*Dipterocarpus indicus* Bedd.	Kalpain	Dipterocarpaceae
72	*Drypetes oblongifolia* (Bedd.) Airy Shaw	Malampayin, Valla	Euphorbiaceae
73	*Drypetes sepiaria* (Wight & Arn.) Pax & K.Hoffm.	Veeramaram, Vellakasavu	Euphorbiaceae
74	*Drypetes venusta* (Wight) Pax &	Palgani	Euphorbiaceae

Sl. No	Species Name	Common Name	Family
	K.Hoffm.		
75	*Dysoxylum malabaricum* Bedd. ex C.DC.	Vellakil	Meliaceae
76	*Elaeocarpus serratus* L.	Kara, Nagara	Elaeocarpaceae
77	*Elaeocarpus tuberculatus* Roxb.	Puzhathanni, Poumbu, Badraksham	Elaeocarpaceae
78	*Elaeocarpus variabilis* Zmarzty	Nakara, Kallukaran	Elaeocarpaceae
79	*Erythrina variegata* L.	Murikku	Fabaceae
80	*Fagraea ceilanica* Thunb.	Marunthankaama ram, Vellamotakam	Gentianaceae
81	*Ficus amplissima* Sm.	Koyali, Chela	Moraceae
82	*Ficus beddomei* King	Chela, Thavittaal	Moraceae
83	*Ficus benghalensis* L.	Peraal	Moraceae
84	*Ficus exasperata* Vahl	Parakam, Therakam	Moraceae
85	*Ficus hispida* L.f.	Erumanakku, Thonditherakam	Moraceae
86	*Ficus racemosa* L.	Atthi	Moraceae
87	*Ficus talbotii* King	Vellayal	Moraceae
88	*Ficus tsjahela* Burm. f.	Kallal, Velmaravu	Moraceae
89	*Filicium decipiens* (Wight & Arn.) Thwaites	Neeroli	Sapindaceae
90	*Flacourtia montana* J.Graham	Kattu-Loobi	Flacourtiaceae
91	*Garcinia gummi-gutta* (L.) N.Robson	Kudapuli	Clusiaceae
92	*Garcinia imbertii* Bourd.	Manjakanji	Clusiaceae
93	*Garcinia indica* (Thouars) Choisy	Punampuli	Clusiaceae
94	*Garcinia cambogioides* var. *cambogioides* (Murray) Headland	Chigiri, Daramba, Iravi	Clusiaceae
95	*Garcinia spicata* (Wight & Arn.) Hook.f.	Manjananku	Clusiaceae
96	*Garcinia wightii* T.Anderson	Attukaruka, Pulimaranga	Clusiaceae
97	*Gliricidia sepium* (Jacq.) Kunth	Sheema Konna	Fabaceae
98	*Glochidion ellipticum* Wight	Neerola	Euphorbiaceae

Sl. No	Species Name	Common Name	Family
99	*Glochidion zeylanicum* var. *zeylanicum* (Gaertn.) A.Juss.	Neervetti	Euphorbiaceae
100	*Gmelina arborea* Roxb. ex Sm.	Kumbil	Verbenaceae
101	*Grewia tiliifolia* Vahl	Chadachi	Tiliaceae
102	*Gymnacranthera farquhariana* (Wall. ex Hook.f. & Thomson) Warb.	Undappayin	Myristicaceae
103	*Adina cordifolia* (Roxb.) Brandis	Manjakadambu	Rubiaceae
104	*Helicteres isora* L.	Idampiri-Valampiri	Sterculiaceae
105	*Heritiera papilio* Bedd.	Cholachadachi, Narumaram	Sterculiaceae
106	*Holigarna arnottiana* Hook.f.	Cheru	Anacardiaceae
107	*Holigarna grahamii* (Wight) Kurz	Kari Cheru, Kattucheru	Anacardiaceae
108	*Holoptelea integrifolia* (Roxb.) Planch.	Aaval	Ulmaceae
109	*Homonoia riparia* Lour.	Attuvanchi	Euphorbiaceae
110	*Hopea indica* (Raf.) R.Kr.Singh	Thambagam	Dipterocarpaceae
111	*Hopea ponga* (Dennst.) Mabb.	Ponk	Dipterocarpaceae
112	*Humboldtia vahliana* Wight	Attuvanchi	Fabaceae
113	*Hydnocarpus alpinus* Wight	Malamaravatti	Flacourtiaceae
114	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Marotty	Flacourtiaceae
115	*Ixora brachiata* Roxb.	Marachethi	Rubiaceae
116	*Prioria pinnata* (Roxb. ex DC.) Breteler	Kulavu	Fabaceae
117	*Knema attenuata* (Wall. ex Hook.f. & Thomson) Warb.	Chorakali, Chorapathiri	Myristicaceae
118	*Lagerstroemia microcarpa* Wight	Venthekku	Lythraceae
119	*Lagerstroemia speciosa* (L.) Pers.	Manimaruthu	Lythraceae
120	*Lannea coromandelica* (Houtt.) Merr.	Kalasu	Anacardiaceae
121	*Lawsonia inermis* L.	Mailanchi	Lythraceae
122	*Leea asiatica* (L.) Ridsdale	Nalugu,Thelv	Leeaceae
123	*Leea guineensis* G. Don	-	Leeaceae
124	*Leea indica* (Burm. f.) Merr.	Njallu	Leeaceae

Sl. No	Species Name	Common Name	Family
125	*Lepisanthes tetraphylla* (Vahl) Radlk.	Naikolli	Sapindaceae
126	*Ligustrum robustum* subsp. *walkeri* (Decne.) P.S.Green	-	Oleaceae
127	*Litsea coriacea* (B.Heyne ex Nees) Hook.f.	Vella Chechukodi, Vettithali	Lauraceae
128	*Litsea floribunda* (Blume) Gamble	Chevukodi	Lauraceae
129	*Lophopetalum wightianum* Arn.	Venkkotta	Celastraceae
130	*Macaranga peltata* (Roxb.) Müll.Arg.	Vatta	Euphorbiaceae
131	*Madhuca neriifolia* (Moon) H.J.Lam	Attu-Ilippa	Sapotaceae
132	*Maesa indica* (Roxb.) Sweet	Kattuvizhal	Myrsinaceae
133	*Maesopsis eminii* Engl.	Kudamaram	Rhamnaceae
134	*Mallotus* spp.	Kattavanakku	Euphorbiaceae
135	*Mallotus atrovirens* Müll.Arg.	-	Euphorbiaceae
136	*Mallotus resinosus* (Blanco) Merr.	Karutha Vellila	Euphorbiaceae
137	*Mallotus philippensis* (Lam.) Müll.Arg.	Kunkumapoo Maram, Sindhooram	Euphorbiaceae
138	*Mangifera indica* L.	Kattumav	Anacardiaceae
139	*Meiogyne pannosa* (Dalzell) J. Sinclair	Vayala Chennari, Panthalmaram	Annonaceae
140	*Melicope lunu-ankenda* (Gaertn.) T.G. Hartley	Nasakam	Rutaceae
141	*Meliosma pinnata* (Roxb.) Maxim.	Kalavi, Thakiri	Sabiaceae
142	*Meliosma simplicifolia* (Roxb.) Walp.	Chengoini, Chenthanam	Sabiaceae
143	*Memecylon angustifolium* Wight	Aattukanala	Melastomataceae
144	*Memecylon grande* Retz.	Palluvriksha	Melastomataceae
145	*Mesua ferrea* L.	Churuli, Nangu	Clusiaceae
146	*Mitragyna parvifolia* (Roxb.) Korth.	Poochakadamb, Neerkadambu	Rubiaceae
147	*Mussaenda frondosa* L.	Vellilamthali	Rubiaceae
148	*Mycetia acuminata* (Wight) Kuntze	-	Rubiaceae
149	*Myristica beddomei* King	Pathripoo, Kattu-Jhadikka	Myristicaceae
150	*Myristica malabarica* Lam.	Pathri	Myristicaceae

Sl. No	Species Name	Common Name	Family
151	*Neolamarckia cadamba* (Roxb.) Bosser	Aattuthekku, Kadambu	Rubiaceae
152	*Neolitsea cassia* (L.) Kosterm.	Keezhambazham, Pravari, Venkana, Vellakodala	Lauraceae
153	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	Oodal, Ottal	Poaceae
154	*Ochlandra travancorica* (Bedd.) Gamble	Eetta	Poaceae
155	*Ochreinauclea missionis* (Wall. ex G.Don) Ridsdale	Aattuvanchi, Neervanchi	Rubiaceae
156	*Tetrapilus dioicus* (Roxb.) L.A.S.Johnson	Edala, Edana	Oleaceae
157	*Oreocnide integrifolia* (Gaudich.) Miq.	Kanavanchi	Urticaceae
158	*Otonephelium stipulaceum* (Bedd.) Radlk.	Vattilapoovam, Poripoovam	Sapindaceae
159	*Palaquium ellipticum* (Dalzell) Baill.	Pali	Sapotaceae
160	*Benstonea foetida* (Roxb.) Callm. & Buerki	Kattukaitha	Pandanaceae
161	*Pandanus furcatus* Roxb.	Attukaitha	Pandanaceae
162	*Paracroton pendulus* (Hassk.) Miq.	Kudavazha, Parorootan	Euphorbiaceae
163	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	Charakonna, Manjvaka	Fabaceae
164	*Machilus macranthus* Nees	Kulamavu	Lauraceae
165	*Phoebe lanceolata* (Nees) Nees	Chiplampatta	Lauraceae
166	*Poeciloneuron indicum* Bedd.	Poothamkolli, Vayila, Vayila Vazha, Vayanavu	Clusiaceae
167	*Monoon coffeoides* (Thwaites ex Hook.f. & Thomson) B.Xue & R.M.K.Saunders	Nedunar	Annonaceae
168	*Monoon fragrans* (Dalzell) B.Xue & R.M.K.Saunders	Nedunar	Annonaceae
169	*Pongamia pinnata* (L.) Pierre	Ungu	Fabaceae
170	*Prismatomeris tetrandra* (Roxb.) K.Schum.	-	Rubiaceae

Sl. No	Species Name	Common Name	Family
171	*Pterocarpus marsupium* Roxb.	Venga	Fabaceae
172	*Pterospermum reticulatum* Wight & Arn.	Malayuram, Malayoorakam	Sterculiaceae
173	*Pterospermum diversifolium* Blume	Pambaram	Sterculiaceae
174	*Putranjiva roxburghii* Wall.	Puthrajeeva	Euphorbiaceae
175	*Radermachera xylocarpa* (Roxb.) Roxb. ex K.Schum.	Kattumuringa	Bignoniaceae
176	*Salix tetrasperma* Roxb.	Attupala, Vanchimaram	Salicaceae
177	*Sapindus trifoliatus* L.	Ulurunji	Sapindaceae
178	*Heptapleurum racemosum* (Wight) Bedd.	Kappamaram	Araliaceae
179	*Heptapleurum venulosum* (Wight & Arn.) Seem.	Ungavalli	Araliaceae
180	*Schleichera oleosa* (Lour.) Oken	Poovam	Sapindaceae
181	*Spondias pinnata* (L. f.) Kurz	Ambazham	Anacardiaceae
182	*Sterculia guttata* Roxb.	Kavalam, Thondi	Sterculiaceae
183	*Stereospermum colais* (Buch.-Ham. ex Dillw.) Mabb.	Pathiri	Bignoniaceae
184	*Strychnos nux-vomica* L.	Kanjiram	Loganiaceae
185	*Symplocos macrophylla* Wall. ex DC.	Malankuruvi	Symplocaceae
186	*Symplocos cochinchinensis* (Lour.) S.Moore	Pachoti	Symplocaceae
187	*Syzygium* Spp.	-	Myrtaceae
188	*Syzygium bourdillonii* (Gamble) Rathakr. & N.C.Nair	-	Myrtaceae
189	*Syzygium chavaran* (Bourd.) Gamble	-	Myrtaceae
190	*Syzygium cumini* (L.) Skeels	Perinjaval, Njaval	Myrtaceae
191	*Syzygium laetum* (Buch.-Ham.) Gandhi	Kollinjaval	Myrtaceae
192	*Syzygium lanceolatum* (Lam.) Wight & Arn.	Njaval	Myrtaceae

Sl. No	Species Name	Common Name	Family
193	*Syzygium occidentale* (Bourd.) Gandhi	Attuchamba, Karinjara	Myrtaceae
194	*Tabernaemontana alternifolia* L.	Kuruttupala	Apocynaceae
195	*Tectona grandis* L.f.	Thekku	Verbenaceae
196	*Terminalia elliptica* Willd.	Karimaruthu	Combretaceae
197	*Terminalia paniculata* B.Heyne ex Roth	Pullmaruthu	Combretaceae
198	*Terminalia travancorensis* Wight & Arn.	Chulamaruthu, Kattukadukka	Combretaceae
199	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Neermaruthu	Combretaceae
200	*Terminalia bellirica* (Gaertn.) Roxb.	Thanni	Combretaceae
201	*Tetrameles nudiflora* R. Br.	Cheenimaram	Datiscaceae
202	*Trema orientale* (L.) Blume	Amathali, Ami	Ulmaceae
203	*Mallotus nudiflorus* (L.) Kulju & Welzen	Naikumbil	Euphorbiaceae
204	*Turpinia malabarica* Gamble	Kambili, Alunkumaram	Staphyleaceae
205	*Staphylea cochinchinensis* (Lour.) Byng & Christenh.	Attuneermulla	Staphyleaceae
206	*Vateria indica* L.	Vellapain	Dipterocarpaceae
207	*Vepris bilocularis* (Wight & Arn.) Engl.	Moothassari	Rutaceae
208	*Strobocalyx arborea* (Buch.-Ham.) Sch.Bip.	Vettilakarintha	Asteraceae
209	*Vitex altissima* L.f.	Myla, Mylellu	Verbenaceae
210	*Vitex leucoxylon* L.f.	Attunochi, Neernochi	Verbenaceae
211	*Wendlandia thyrsoidea* (Roth) Steud.	Vellathalachedi, Pekanarakam	Rubiaceae
212	*Wrightia tinctoria* (Roxb.) R.Br.	Dhanthapala	Apocynaceae
213	*Xanthophyllum flavescens* Roxb.	Madakka	Polygalaceae
214	*Xylia xylocarpa* (Roxb.) W.Theob.	Irumul,Irul	Fabaceae
215	*Ziziphus rugosa* Lam.	Thodali, Kottamullu	Rhamnaceae

APPENDIX - VII

Dominant families of the riparian forests (tree species) of the Anamalai landscape

Sl. No.	Name of Family	Number of Genus	Number of Species
1	Euphorbiaceae	13	22
2	Fabaceae	13	16
3	Lauraceae	7	12
4	Clusiaceae	4	11
5	Moraceae	2	10
6	Rubiaceae	9	9
7	Ebenaceae	1	8
8	Myrtaceae	1	8
9	Sapindaceae	7	7
10	Anacardiaceae	5	6
11	Combretaceae	1	5
12	Meliaceae	3	5
13	Sterculiaceae	4	5
14	Annonaceae	3	4
15	Dipterocarpaceae	3	4
16	Myristicaceae	3	4
17	Rutaceae	4	4
18	Verbenaceae	3	4
19	Apocynaceae	3	3
20	Bombacaceae	3	3
21	Elaeocarpaceae	1	3
22	Flacourtiaceae	2	3
23	Leeaceae	1	3
24	Lythraceae	2	3
25	Oleaceae	3	3
26	Poaceae	2	3
27	Urticaceae	3	3

Sl. No.	Name of Family	Number of Genus	Number of Species
28	Araliaceae	1	2
29	Arecaceae	2	2
30	Bignoniaceae	2	2
31	Capparaceae	2	2
32	Celastraceae	2	2
33	Lamiaceae	2	2
34	Melastomataceae	1	2
35	Pandanaceae	2	2
36	Rhamnaceae	2	2
37	Sabiaceae	1	2
38	Sapotaceae	2	2
39	Staphyleaceae	2	2
40	Symplocaceae	1	2
41	Ulmaceae	2	2
42	Alangiaceae	1	1
43	Asteraceae	1	1
44	Burseraceae	1	1
45	Chrysobalanaceae	1	1
46	Datiscaceae	1	1
47	Dilleniaceae	1	1
48	*Gentianaceae*	1	1
49	Lecythidaceae	1	1
50	Loganiaceae	1	1
51	Myrsinaceae	1	1
52	Polygalaceae	1	1
53	Rhizophoraceae	1	1
54	Salicaceae	1	1
55	Simaroubaceae	1	1
56	Solanaceae	1	1
57	Tiliaceae	1	1

APPENDIX - VIII

Endemic tree species of riparian zones of the Anamalai landscape

Sl. No.	Name of the Species	Family	Endemism
1	*Actinodaphne wightiana* (Kuntze) Noltie	Lauraceae	Southern Western Ghats
2	*Actinodaphne bourdillonii* Gamble	Lauraceae	Southern Western Ghats
3	*Aporosa acuminata* Thwaites	Euphorbiaceae	Peninsular India and Sri Lanka
4	*Aporosa bourdillonii* Stapf	Euphorbiaceae	Southern Western Ghats (Kerala)
5	*Arenga wightii* Griff.	Arecaceae	Western Ghats
6	*Atuna travancorica* (Bedd.) Kosterm.	Chrysobalanaceae	Southern Western Ghats
7	*Baccaurea courtallensis* (Wight) Müll.Arg.	Euphorbiaceae	Peninsular India
8	*Calophyllum austroindicum* Kosterm. ex P.F.Stevens	Clusiaceae	Southern Western Ghats
9	*Calophyllum calaba* L.	Clusiaceae	Western Ghats
10	*Capparis rheedei* DC.	Capparaceae	Western Ghats
11	Chionanthus mala-elengi (Dennst.) P.S. Green subsp. *mala-elengi*	Oleaceae	Peninsular India
12	*Cinnamomum macrocarpum* Hook.f.	Lauraceae	Southern Western Ghats
13	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Lauraceae	Southern Western Ghats
14	*Cinnamomum riparium* Gamble	Lauraceae	Southern Western Ghats
15	*Cinnamomum sulphuratum* Nees	Lauraceae	Western Ghats
16	*Cullenia exarillata* A.Robyns	Bombacaceae	Southern Western Ghats
17	*Diospyros candolleana* Wight	Ebenaceae	Peninsular India
18	*Diospyros paniculata* Dalzell	Ebenaceae	Peninsular India
19	*Dipterocarpus indicus* Bedd.	Dipterocarpaceae	Western Ghats
20	*Drypetes venusta* (Wight) Pax & K. Hoffm.	Euphorbiaceae	Southern Western Ghats

Sl. No.	Name of the Species	Family	Endemism
21	*Dysoxylum malabaricum* Bedd. ex C. DC.	Meliaceae	Southern Western Ghats
22	*Elaeocarpus variabilis* Zmarzty	Elaeocarpaceae	Western Ghats
23	*Ficus beddomei* King	Moraceae	Western Ghats
24	*Flacourtia montana* J.Graham	Flacourtiaceae	India
25	*Garcinia imbertii* Bourd.	Clusiaceae	Southern Western Ghats
26	*Garcinia indica* (Thouars) Choisy	Clusiaceae	Western Ghats
27	*Garcinia wightii* T.Anderson	Clusiaceae	Southern Western Ghats
28	*Heptapleurum racemosum* (Wight) Bedd.	Araliaceae	Western Ghats
29	*Holigarna arnottiana* Hook.f.	Anacardiaceae	Southern Western Ghats
30	*Holigarna grahamii* (Wight) Kurz	Anacardiaceae	Western Ghats
31	*Hopea indica* (Raf.) R.Kr.Singh	Dipterocarpaceae	Southern Western Ghats
32	*Hopea ponga* (Dennst.) Mabb.	Dipterocarpaceae	Southern Western Ghats
33	*Humboldtia vahliana* Wight	Fabaceae	Southern Western Ghats
34	*Hydnocarpus pentandrus* (Buch. -Ham.) Oken	Flacourtiaceae	Western Ghats
35	*Ixora brachiata* Roxb.	Rubiaceae	Western Ghats
36	*Knema attenuata* (Wall. ex Hook. f. & Thomson) Warb.	Myristicaceae	Western Ghats
37	*Lagerstroemia microcarpa* Wight	Lythraceae	Southwest India
38	*Litsea coriacea* (B.Heyne ex Nees) Hook. f.	Lauraceae	Peninsular India
39	*Litsea floribunda* (Blume) Gamble	Lauraceae	Western Ghats
40	*Mallotus atrovirens* Müll.Arg.	Euphorbiaceae	Southern Western Ghats
41	*Meiogyne pannosa* (Dalzell) J. Sinclair	Annonaceae	Western Ghats
42	*Monoon fragrans* (Dalzell) B.Xue & R.M.K.Saunders	Annonaceae	Southern Western Ghats
43	*Mussaenda frondosa* L.	Rubiaceae	South Asia

Sl. No.	Name of the Species	Family	Endemism
44	*Mycetia acuminata* (Wight) Kuntze	Rubiaceae	Western Ghats
45	*Myristica beddomei* King	Myristicaceae	South India
46	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	Poaceae	Western Ghats
47	*Ochlandra travancorica* (Bedd.) Gamble	Poaceae	Southern Western Ghats
48	*Ochreinauclea missionis* (Wall. ex G.Don) Ridsdale	Rubiaceae	Western Ghats
49	*Otonephelium stipulaceum* (Bed d.) Radlk.	Sapindaceae	Western Ghats
50	*Palaquium ellipticum* (Dalzell) Baill.	Sapotaceae	Western Ghats
51	*Poeciloneuron indicum* Bedd.	Clusiaceae	Western Ghats
52	*Radermachera xylocarpa* (Roxb.) Roxb. ex K.Schum.	Bignoniaceae	Peninsular India
53	*Symplocos macrophylla* Wall. ex DC.	Symplocaceae	Southern Western Ghats
54	*Syzygium mundagam* (Bourd.) Chithra	Myrtaceae	Southern Western Ghats
55	*Syzygium occidentale* (Bourd.) Gandhi	Myrtaceae	Southern Western Ghats
56	*Syzygium bourdillonii* (Gamble) Rathakr. & N.C.Nair	Myrtaceae	Southern Western Ghats
57	*Syzygium cumini* (L.) Skeels	Myrtaceae	Southern Western Ghats
58	*Syzygium laetum* (Buch.-Ham.) Gandhi	Myrtaceae	Southern Western Ghats
59	*Tabernaemontana alternifolia* L .	Apocynaceae	South West India
60	*Terminalia paniculata* B.Heyne ex Roth	Combretaceae	Peninsular India
61	*Terminalia travancorensis* Wight & Arn.	Combretaceae	Western Ghats
62	*Tetrapilus dioicus* (Roxb.) L.A.S.Johnson	Oleaceae	India to Myanmar
63	*Vateria indica* L.	Dipterocarpaceae	Western Ghats
64	*Vepris bilocularis* (Wight & Arn.) Engl.	Rutaceae	Southern Western Ghats

APPENDIX - IX

IUCN threatened tree species of riparian zones of the Anamalai landscape (Accessed on 30.06.2024)

Sl. No.	Name of the Species	Family	IUCN Status
1	*Garcinia imbertii* Bourd.	Clusiaceae	CR
2	*Diospyros crumenata* Thwaites	Ebenaceae	CR
3	*Atuna travancorica* (Bedd.) Kosterm.	Chrysobalanaceae	EN
4	*Garcinia wightii* T.Anderson	Clusiaceae	EN
5	*Dipterocarpus indicus* Bedd.	Dipterocarpaceae	EN
6	*Aporosa bourdillonii* Stapf	Euphorbiaceae	EN
7	*Humboldtia vahliana* Wight	Fabaceae	EN
8	*Cinnamomum riparium* Gamble	Lauraceae	EN
9	*Dysoxylum malabaricum* Bedd. ex C.DC.	Meliaceae	EN
10	*Ficus beddomei* King	Moraceae	EN
11	*Syzygium occidentale* (Bourd.) Gandhi	Myrtaceae	EN
12	*Syzygium bourdillonii* (Gamble) Rathakr. & N.C.Nair	Myrtaceae	EN
13	*Syzygium chavaran* (Bourd.) Gamble	Myrtaceae	EN
14	*Tectona grandis* L.f.	Verbenaceae	EN
15	*Arenga wightii* Griff.	Arecaceae	VU
16	*Garcinia indica* (Thouars) Choisy	Clusiaceae	VU
17	*Hopea ponga* (Dennst.) Mabb.	Dipterocarpaceae	VU
18	*Vateria indica* L.	Dipterocarpaceae	VU
19	*Diospyros candolleana* Wight	Ebenaceae	VU
20	*Diospyros paniculata* Dalzell	Ebenaceae	VU

Sl. No.	Name of the Species	Family	IUCN Status
21	*Aporosa cardiosperma* (Gaertn.) Merr.	Euphorbiaceae	VU
22	*Mallotus atrovirens* Müll.Arg.	Euphorbiaceae	VU
23	*Dalbergia latifolia* Roxb.	Fabaceae	VU
24	*Prioria pinnata* (Roxb. ex DC.) Breteler	Fabaceae	VU
25	*Hydnocarpus alpinus* Wight	Flacourtiaceae	VU
26	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Flacourtiaceae	VU
27	*Cinnamomum macrocarpum* Hook. f.	Lauraceae	VU
28	*Cinnamomum sulphuratum* Nees	Lauraceae	VU
29	*Memecylon grande* Retz.	Melastomataceae	VU
30	*Aglaia perviridis* Hiern	Meliaceae	VU
31	*Myristica malabarica* Lam.	Myristicaceae	VU
32	*Ochreinauclea missionis* (Wall. ex G.Don) Ridsdale	Rubiaceae	VU
33	*Pterospermum reticulatum* Wight & Arn.	Sterculiaceae	VU
34	*Meiogyne pannosa* (Dalzell) J. Sinclair	Annonaceae	NT
35	*Pterocarpus marsupium* Roxb.	Fabaceae	NT
36	*Actinodaphne bourdillonii* Gamble	Lauraceae	NT
37	*Litsea coriacea* (B.Heyne ex Nees) Hook.f.	Lauraceae	NT
38	*Litsea floribunda* (Blume) Gamble	Lauraceae	NT
39	*Aglaia edulis* (Roxb.) Wall.	Meliaceae	NT

*CR- Critically Endangered, EN- Endangered, VU- Vulnerable and NT- Near Threatened

APPENDIX - X

Taxa (S), Individuals, Dominance (D), Evenness (E^H/S), & Diversity indices for the identified clusters of the Anamalai landscape

Sl No.	Major Cluster	Sub Cluster	Taxa (S)	No. of Individuals	Dominance (D)	Simpson index (1-D)	Shannon index (H)	Evenness (e^H/S)
1	Cluster - 1	Sub Cluster - 1a	9	20	0.09474	0.9053	2.268	1.074
2		Sub Cluster - 1b	9	25	0.2681	0.7319	1.735	0.7085
3		Sub Cluster - 1c	5	9	0.1111	0.8889	1.803	1.214
4		Sub Cluster - 1d	29	96	0.09145	0.9086	2.965	0.6687
5	Cluster - 2	Sub Cluster - 2a	3	10	0.4667	0.5333	0.7198	1.027
6		Sub Cluster - 2b	4	10	0.2222	0.7778	1.43	1.045
7	Cluster - 3	Sub Cluster - 3a	9	25	0.1377	0.8623	2.041	0.9627
8		Sub Cluster - 3b	6	16	0.125	0.875	1.91	1.126
9	Cluster - 4	Sub Cluster - 4a	10	22	0.1472	0.8528	2.201	0.903

Sl No.	Major Cluster	Sub Cluster	Taxa (S)	No. of Individuals	Dominance (D)	Simpson index (1-D)	Shannon index (H)	Evenness (e^H/S)
10		Sub Cluster - 4b	8	46	0.2556	0.7444	1.549	0.6726
11	Cluster - 5	Sub Cluster - 5a	8	20	0.1765	0.8235	1.886	0.942
12		Sub Cluster - 5b	14	74	0.1233	0.8767	2.416	0.8001
13	Cluster - 6	Sub Cluster - 6a	40	91	0.06789	0.9321	3.387	0.7395
14		Sub Cluster - 6b	39	115	0.04363	0.9564	3.475	0.8284
15		Sub Cluster - 6c	51	299	0.07243	0.9276	3.292	0.5271
16		Sub Cluster - 6d	31	67	0.03256	0.9674	3.456	1.022
17		Sub Cluster - 6e	20	60	0.07288	0.9271	2.839	0.8553
18	Cluster - 7	Sub Cluster - 7a	39	311	0.3572	0.6428	2.056	0.2004
19		Sub Cluster - 7b	35	322	0.1595	0.8405	2.598	0.3838
20		Sub Cluster - 7c	31	966	0.6665	0.3335	0.9013	0.07944

Sl No.	Major Cluster	Sub Cluster	Taxa (S)	No. of Individuals	Dominance (D)	Simpson index (1-D)	Shannon index (H)	Evenness (e^H/S)
21	Cluster - 8	Sub Cluster - 8a	5	30	0.3379	0.6621	1.253	0.6999
22		Sub Cluster - 8b	32	209	0.4521	0.5479	1.753	0.1803
23	Cluster - 9	Sub Cluster - 9a	14	64	0.1091	0.8909	2.472	0.8458
24		Sub Cluster - 9b	20	62	0.08514	0.9149	2.784	0.8093
25		Sub Cluster - 9c	23	48	0.04638	0.9536	3.1	1.009
26		Sub Cluster - 9d	47	129	0.03765	0.9624	3.603	0.7983
27		Sub Cluster - 9e	21	52	0.04549	0.9545	3.046	1.051
28		Sub Cluster - 9f	16	45	0.08889	0.9111	2.649	0.8836
29		Sub Cluster - 9g	29	99	0.04556	0.9544	3.255	0.894
30	Cluster -10	Sub Cluster - 10	19	66	0.11	0.89	2.584	0.6974
31	Cluster -11	Sub Cluster -11a	16	101	0.26	0.74	2.054	0.4873

Sl No.	Major Cluster	Sub Cluster	Taxa (S)	No. of Individuals	Dominance (D)	Simpson index (1-D)	Shannon index (H)	Evenness (e^H/S)
32		Sub Cluster - 11b	10	32	0.1204	0.8796	2.169	0.9718
33	Odd Groups	Sub Cluster - O1	6	11	0.1333	0.8667	1.757	1.159
34		Sub Cluster - O2	10	18	0.1691	0.8309	2.104	0.9111
35		Sub Cluster - O3	10	44	0.1628	0.8372	2	0.8208
36		Sub Cluster - O4	3	7	0.3333	0.6667	0.8181	1.133

APPENDIX – XI

List of publications and presentations

A. Publications in Journals

1. Pooja, S., Sidhardh, A. S. K., & Bachan, A.K.H. (2020). **Biodiversity significance of low-elevation riparian forests in Vazhachal: conservation and restoration implications**. *Journal of Aquatic Biology & Fisheries*, *8*, 77-82.
2. Pooja, S., & Bachan, A.K.H. (2020). **Impact of forestry practices on primary natural forests in the Western Ghats: A case study from Vazhachal forest division, Kerala**. *Meridian*, *9* (2), 76-86.

B. Publications as Book Chapters

1. Bachan, A.K.H., Pooja, S., & Devika, M.A. (2022). **Riparian forest of Western Ghats, an endangered ecosystem.** In D.A. Della Sala, & M.I. Goldstein (Eds.), *Imperiled: The Encyclopedia of Conservation* (pp. 100 - 113) Elsevier.
2. Pooja, S., & Bachan, A.K.H. (2019). **Mazhakkadugalude shoshana charithram**. In *Vezhambal Samrakshanathinte Rand Dhashakagal* (pp. 67-71). Niche publications.
3. Bachan, A.K.H., & Pooja, S. (2019). **Ecorestoration and biodiversity conservation of riparian forests along the Chalakudy River Southern Western Ghats**. *Biodiversity for climate resilience* (pp. 72-76). Kerala State Biodiversity Board.

C. Paper presentations (National and International Conferences)

1. **Distribution of riparian vegetation within the Anamalai landscape unit, Western Ghats,** in the Annual Research Conclave & International Conference on Advancement in Research (ESPLORO-23), held at MES Asmabi College, P. Vemballur, on 29th & 30^{th} March 2023.
2. **Mapping the riparian vegetation within Anamalai** in the International Conference on Riparian Forest for Fish, Rivers and People towards

ecological management of rivers on World Fish Migration Day 2022, jointly organised by Western Ghats Hornbill Foundation, MES Asmabi College, P. Vemballur, Department of aquatic biology and fisheries, University of Kerala and World Fish Migration Foundation, Netherlands, on 21st May 2022.

3. **Riparian forests in the rain shadow region of the Western Ghats: A case study on the Chinnar River, Anamalai's,** in the 31st Annual Conference of Indian Association for Angiosperm Taxonomy (IAAT) and International Conference on Documentation, Bioprospecting and Conservation of Biodiversity for Sustainable Development held at Kalsubai Wild Life Sanctuary, Bandardhara, Maharashtra, on 5th to 7th April 2022.
4. **Riparian forest types in Kerala: An addition to Champion and Seth forest classification, 1968,** in Three days International Conference on "Rivers for Future" Department of Aquatic Biology and Fisheries, University of Kerala on 05th to 07th February 2020.
5. **Methodology for ecorestoration of degraded forest lands,** in the National Conference on *Democracy, Land, and Resource Management Rights of Adivasis and challenges of strengthening Adivasi Grama Sabhas in Kerala*, held at M.E. S Asmabi College, P.Vemballur, Thrissur on 18th& 19th December 2019.
6. **Impact of landslide and flood on forest ecosystems with special reference to riparian forests in the Vazhachal forest division, Western Ghats,** in the MES Asmabi Golden Jubilee conference (MESAC 2019) held at M.E. S Asmabi College, P.Vemballur, Thrissur on 19th& 20th March 2019.
7. **Impact of forestry practices on primary natural forests in the Western Ghats: A case study from Vazhachal forest division, Kerala,** in the 31st Kerala Science Congress held at Fathima Matha National College, Kollam on 2nd & 3rd February 2019.

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CERTIFICATE ON PLAGIARISM CHECK

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3.	Name of the Supervisor	Dr. Amitha Bachan K.H.	
4.	Department/Institution	Research Department of Botany, M.E.S Asmabi College, P.Vemballur, Thrissur, Kerala	
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