KFRI Research Report No.549 ISSN No. 0970-8103

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(Report of project KFRI RP-627.2/11)

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ABSTRACT OF THE PROJECT PROPOSAL

Project Number : KFRI RP-627.2/11

Title : Establishment of permanent plots in all forest types for continuous monitoring of climate change induced variations

Objective : To establish permanent plots in all forest types for continuous monitoring

Project period : August 2011 - July 2013

Funding agency : KFRI Plan Grants

Investigators : V.B. Sreekumar, K. A. Sreejith, T. V. Sajeev

Research Fellows : Hareesh V S & Nirmesh T K

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ACKNOWLEDGEMENTS

The authors are thankful to Dr. K. V. Sankaran, Dr. P. S. Easa, Dr. P. G. Latha and Dr. B. S. Corrie IFS, former Directors; Dr. K. Pradeepkumar, Member Secretary and Director in charge, KFRI; Dr. K. Balagopalan and Dr. E. A. Jayson former Research Coordinators and, Dr. T. V., Sajeev, Research Coordinator, KFRI for their keen interest in providing all facilities for the implementation and completion of the project. We are grateful to the Executive Vice President for financial support of Kerala State Council for Science, Technology and Environment (KSCSTE), Thiruvananthapuram for this programme. We also express our sincere thanks to officials of the Kerala Forest Department for permission to conduct the study and help during the field work.

ABSTRACT

Long term monitoring plots provide vital information on the flora, vegetation ecology, ecosystem dynamics, climate change and anthropogenic impact on biodiversity. Six, one hectare permanent plots were established in evergreen, moist deciduous, dry deciduous and shola forests for long term monitoring to analyse the pattern of ecosystem dynamics and temporal changes in the floristic and biodiversity composition. Each one ha plot was in turn subdivided into 100 quadrats of 10 x 10 m size, with quadrats permanently marked. A total of 5904 individuals were counted which constituted 149 species. Number of individuals was greater in evergreen forests of two sites (1905 individuals ha^{-1} and 1393 individuals ha^{-1}), followed by shola forest (738 individuals ha^{-1}), moist deciduous forest (703 individuals ha^{-1}) and dry deciduous forest (286 individuals ha^{-1}). Species-level basic information such as location of trees in plots, girth distribution pattern and frequency of distribution in different forest was generated which form the baseline information for monitoring the changes. Further, these plots can be used for monitoring of species wise regeneration pattern, phenology, seed dispersal, soil micro-flora etc.,

1. INTRODUCTION

Tropical rain forests have been revered as the most species-rich biome on Earth, harbouring over 50% of species on just 7% of the land area (Wilson, 1988). During the last few years, tropical rain forests are undergoing rapid ranging changes in land cover at an alarming rate. In order to understand how these species are maintained in these forests over time, and how they are affected by human activities such as logging and forest fragmentation, research on their demography is needed. Hence, assessing and monitoring changes in natural tropical forests has received considerable attention in past few years, with issues connected to deforestation, climate change, carbon storage, or forest exploitation (Lovett et al., 2007). To understand the process that drive these changes, or to get a finer description of them, repeated field measurements are required in plots maintained on a long term basis.

Permanent plots are 'accurately marked plots, where assessing and monitoring changes in vegetation repeatedly over a period of time, at least more than once'. These are commonly used to monitor vegetation changes (Strayer, et al., 1986; Vanclay 1991; Bakker et al., 1996; Priyadi et al., 2006) and through repeatedly monitoring trees over a period of time, population demographic parameters such as survival rates, pattern of regeneration, recruitments rates, and growth rates, can be estimated. The procedure for monitroing permanent plots in mixed tropical forests have been studied for a long time, and were formulated in the 1990s (Alder and Synnott 1992; Dallmeier 1992). The designing the choice of plot size, plot shape, the number of replicated plots and the census intervals are also deserves special attention. A rationale for choosing the size and number of permanent plots for long term monitoring is scanty; as contrasted situations are found, with permanent plots ranging from 1,000m^2 (Gentry, 1992) to 50 ha (Losos and Leigh, 2004). Compared to smaller plots, larger plots also have several advantages: a more diverse representation of life forms; the gradient of species commonality and rarity become apparent; site monitoring of dynamic changes in the ecosystem can be undertaken continuously (Bakker *et al.* 1996, Herben 1996). The minimum size recommended for a permanent plot is one hectare below which the species diversity and dynamic processes are poorly estimated. Several studies have shown that estimates of species diversity and richness are higher

when many small plots are sampled, as compared to a few but larger plots (Parsons & Cameron 1974, Whitmore 1984, Whitmore *et al.* 1985). With regard to the period of census interval in permanent plots, Alder and Synnott (1992), Dallmeier (1992) and Sheil (1997) considered that 5 years is generally considered as a suitable census interval. The influences of the census interval on the estimation of survival and recruitment rates are also well addressed (Kubo et al., 2000; Lewis et al., 2004).

Globally, the forest dynamics plots expanded since its origin in the early 1980s, yet research at the plots has remained integrated due to a combination of individual scientists' efforts and institutional commitments from the Center for Tropical Forest Science (CTFS, <www.ctfs.si.edu>) of the Smithsonian Tropical Research Institute and the Arnold Arboretum of Harvard University (Hubbell and Foster 1983, Condit 1995). Similarly as part of Smithsonian Institution/MAB Biological Diversity Program (SI/MAB), permanent forest inventory plots were tested and refined at field sites in Bolivia, Peru, Puerto Rico, and the US Virgin Islands, as well as in Great Smoky Mountains National Park during the period 1987-1991. The Center for Tropical Forest Science - Forest Global Earth Observatory (CTFS-ForestGEO) is a global network of forest research plots and scientists dedicated to the study of tropical and temperate forest function and diversity. The multi-institutional network comprises over 60 forest research plots across the Americas, Africa, Asia, and Europe, with a strong focus on tropical regions. CTFS-Forest GEO monitors the growth and survival of approximately 6 million trees and 10,000 species. The protocol is standard (Condit 1998) for all sites, including the marking, mapping, and measuring of all trees and shrubs with stem diameters ≥1 cm. CTFS established the first 50 ha plot at Barro Colorado Island in Panama in 1980, with 1000 meter by 500 meter rectangle of forest inside of which all woody trees and shrubs with stems at least 1 cm in stem diameter have been censused. Every individual tree in the 50 hectares was permanently numbered with an aluminum tag in 1982, and every individual has been revisited six times since (in 1985, 1990, 1995, 2000, 2005, and 2010). The data from all seven censuses, including 394,000 individual trees and 1.58 million diameter measurements, are available as a Smithsonian archive (http://dx.doi.org/10.5479/data.bci.20130603).

Forest observational studies in India

In India, long term forest research sites are known different names including Linear Tree Increment Plots, Linear Increment Plots, Linear Sample Plots and Permanent Preservation Plots, which cover diverse plant communities and environmental conditions (Tiwari et al., 2014). Coming to the early observational studies, there are the plots established by State Forest Departments and Forest Research Institutes for monitoring tree mortality and assessing diameter and basal area increment of trees at periodic interval. In Karnataka, there are plots in tropical rain forests established during 1911–1920 and 1937–1939 and tropical moist deciduous forests during 1950–1953. Similarly plots in the tropical rainforest in Assam (1958), Kerala and Tamil Nadu (1938); teak plots in Maharashtra (1931), Karnataka (1951–1953) and Kerala (1938); plots of *Shorea robusta* in Uttar Pradesh (1935–1939), Bihar (1936–1959) and West Bengal (1924–1926); sandal plots in Karnataka (1934–1935), Andhra Pradesh (1937) and Tamil Nadu (1936); plots of *Pterocarpus santalinus* in Andhra Pradesh are few others in this category. As an outcome of Third Silvicultural Conference at Dehradun, in 1929, Forty-eight standardised Linear Tree Increment (LTI) plots with 20 m in width and of varying length, are distributed among 17 forest divisions (Tiwari et al., 2014). There are Linear Increment Plots, in Dibrugarh and Digboi forest division of Assam established during 1958–1978 and moist and dry deciduous forests of the Haldwani, Kalagarh, Ram Nagar, North Kheri, West Baharaich and Dehradun forest division of UP established during 1935–1939. The Silviculture Division of the Forest Research Institute in Dehradun, in collaboration with State Forest Departments, was responsible for maintaining a total of 155 Preservation Plots throughout in India. This was proposed by Sir H.G. Champion, during his presentation at Third Silvicultural Conference in 1929 (Khuller, 1992) and the Fifth All India Silvicultural Conference finalised detailed instructions regarding lay out, maintenance and records of Preservation Plots and the minimum area recommended for such plots was 8 ha. The oldest Preservation Plot appears to have been established in 1905 in the *S. robusta* forests of Bihar (Kaul et al., 1975).

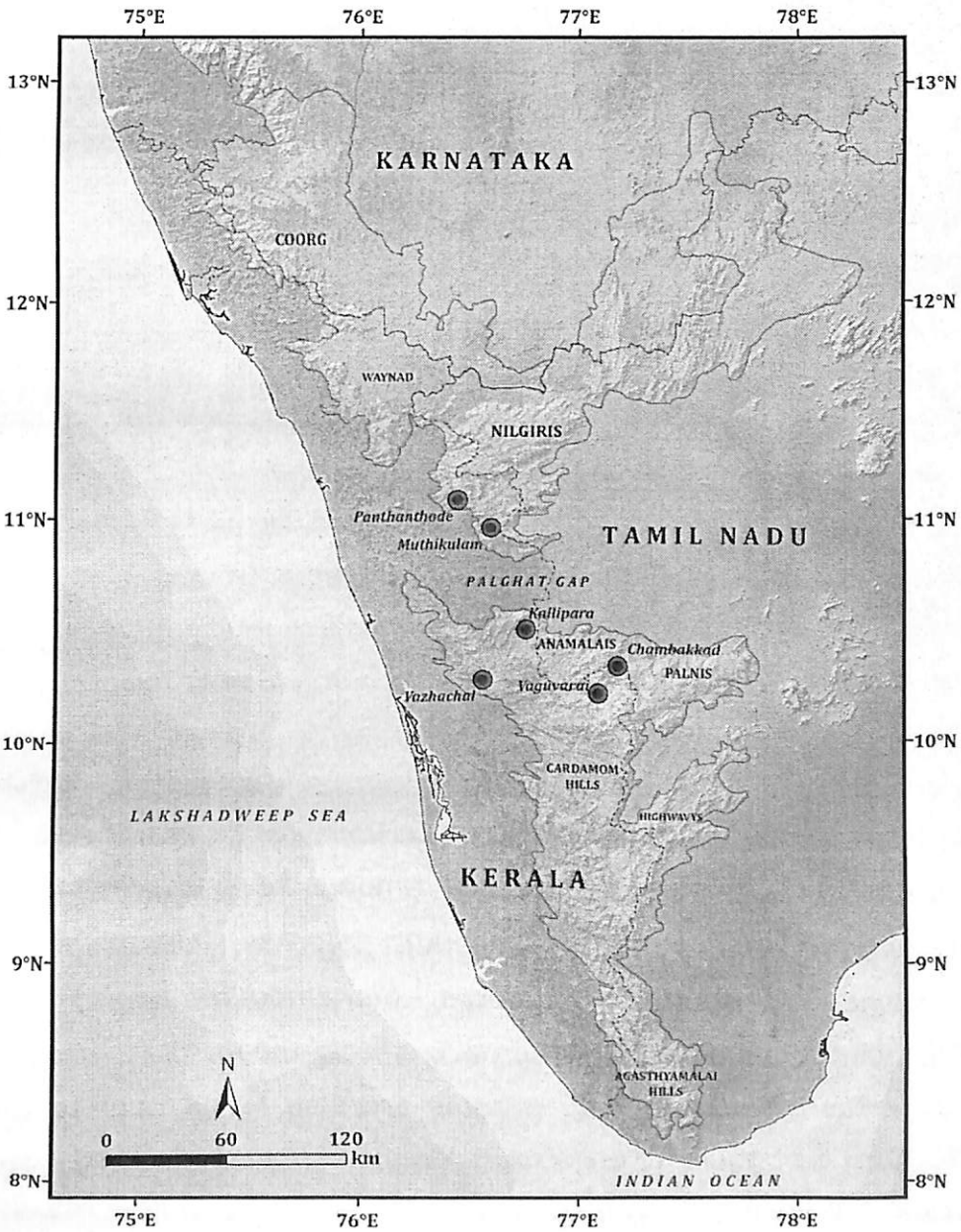
Among the Permanent Sample Plots (PSPs), the first 50-ha forest dynamics plots was established in 1988, at Mudumalai Wildlife Sanctuary (Tamil Nadu) in the

eastern foothills of the Western Ghats of southern India by the Centre for Ecological Sciences of the Indian Institute of Science, Bangalore (India), following protocols for large-scale plots established by the Smithsonian Tropical Research Institute (Sukumar et al., 1992; Condit, 1998). In 1990, the French Institute of Pondicherry and Karnataka Forest Department established 28 ha forest dynamics plot at Uppangala forests areas of Coorg District for studying the functioning and dynamics of disturbed and undisturbed wet evergreen dipterocarps forests in the Western Ghats. A permanent plot of 30 ha (600 x 500 m^2) was established for long-term ecological research on biodiversity and forest functioning in a tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats (Ayyappan and Parthasarathy, 1999). In natural forests of Kerala, Kerala Forest Research Institute (KFRI) is maintaining more than 25 permanent sample plots. Nair and Balasubramanyan (1985) established 0.25 ha permanent plots in different locations of Muthikkulam, Silent valley, Idukki and Nelliampathy. While evaluating plant diversity in different forest types of Kerala, Chandrashekara *et al.*, (1998) established 1 ha permanent plots in Eravikkumam National Park, Pothumala, Channakkad and Chinnar Wildlife Sanctuary. There are semi-permanent plots in Shola forests of Eravikkulam established as a part of floristic diversity and phyto-sociology of Shola forests of Kerala (Swarupanandan et al., 1998). As a part of investigation on stand structural diversity and dynamics in natural forests of Kerala, Chandrashekara and Jayaraman (2002) established sixty permanent plots, each of 100 m x 50 m in size (0.5 ha in area) to represent major forest types viz. shola forest, evergreen forest, semi-evergreen forest, moist deciduous forest and dry deciduous forest in Kerala. In this study. Each 0.5 ha plot was in turn subdivided into 50 quadrats of 10 m x 10 m size, with quadrats permanently marked. However due to lack of maintenance most these plots established in the earlier studies was could not be traceable and traced 14 plots in different forest ecosystems are permanently maintained (Sreejith, Personal communication). In the present study, 1 ha plots of 10 x 10 m quadrat was established in different forest ecosystems for long term monitoring. This will be useful for understanding the long term dynamics including tree mortality changes, pattern of regeneration, phenology, carbon and soil changes as well as long term monitoring of associated faunal elements.

2. MATERIALS AND METHODS

Site descriptions

Six sites representing different forest types (Map 2.1), each one to represent a type of forest namely high altitude shola forest, wet evergreen forest, moist deciduous forest and dry deciduous forest have been selected for establishing permanent plots. The site details are provided in Table 2.1



Map 2.1. Map showing location of Permanent plots

Table 2.1. Details of Forest sites selected in Kerala for the establishment of permanent sample plots

Plot Code No.	Forest Type*	Locality	Forest Range	Forest Division	Altitude (m)	Longitude	Latitude
1	Shola/ Grassland	Vaguvarai	Eravikulam	Eravikulam NP	1926	77.16472	10.31722
2	DDF	Champakad	Chinnar	Chinnar WLS	514	77.0686	10.0498
3	EG	Silent Valley	Silent Valley	Silent valley NP	943	76.283	11.0533
4	EG	Vazhachaal	Vazhachaal	Chalakudi	461	76.657511	10.299742
5	MDF	Kallipara	Parambikulam	Parambikulam WLS	638	76.81394	10.4091
6	EG	Muthikkulam	Attapady	Mannarkkad	840	76.625444	10.986972

* EG= Evergreen Forests, DDF= Dry Deciduous Forests, MDF= Moist Deciduous Forests.

Brief description of the sites follows:

Tropical montane forest (Shola) at Vaguvarai

The Vaguvarai Shola is located in the Eravikkulam Range of Eravikkulam National Park, and the present plot is located 10^0 31' N latitude and 77^0 16' E longitude. The elevation of approximately 1,950 msl and altitude ranges between 1600-2400 m and the mean annual temperature is 20° C. The mean annual precipitation recorded is 2000 mm - 3000 mm. The coldest months are December and January when the minimum temperature inside forests falls up to 6^0C even at lower elevations. The soil is red, sandy loam, oxysol, acid (pH = 4.2) with 4.6% to 14% organic carbon content. The vegetation mainly comprises of Southern Subtropical Hill Forests which gradually transform to the Southern Montane Wet Temperare Forests (Champion and Seth, 1968) towards the top regions. Among trees, the first five dominant species are *Hydnocarpus alpina*, *Isonandra stocksii*, *Gomphandra coriacea*, *Lasianthus alpina*, *Chionanthus ramiflorus*, *Cinnamomum wightii* and *Mastixia arborea*. The plantations of exotic trees like *Acacia mearnsii*, *A. dealbata*, *Prunus persica*, *Eucalyptus globulus* and *E. grandis* are also found near to the adjacent areas. At 2000 m also there is an ecotonal region characterized by reed bamboos such as *Karuna floribunda*, *K. walkeriana* and *K. densiflora* while a maximum height of 28-31 m is observed at 1800-1900 m altitude, contributed by different species of

Syzygium such as *S. densiflorum*, *S. gardneri*, *S. caryophyllatum*, *S. cumini*, *Elaeocarpus glandulosus*, etc. Other species include *Rhodomyrtus tomentosa*, *Daphniphyllum neilgherrense*, *Pipttosporum tetraspermum*, *Rhododendron arboreum* subsp. *nilagiricum*, *Vaccinium leschenaultia*, *Hypericum mysorense*, *Ilex walkeri*, etc., Above 2100 m, sholas are found as patches confined to gullies and depressions often veiling small streams flowing through them. The size of these shola patches decrease by altitude and at 2400 m region, only a few such patches are seen those encircled by grasslands where planting by *Acacia* and *Eucalyptus* were carried out in the past. For establishing 1 ha permanent plot, relatively undisturbed patch of the shola forest is selected (Figure 2.1).

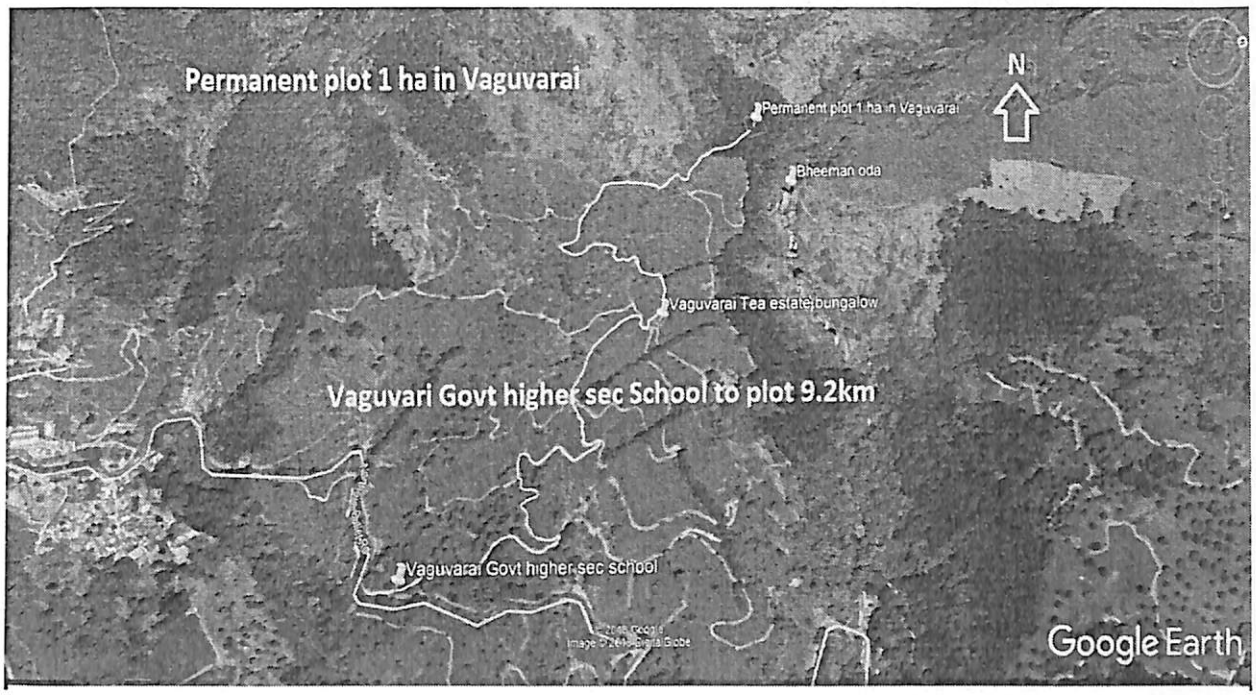


Figure 2.1. Location Map of 1 ha plot at Vaguvarai Shola

Tropical evergreen forest at Muthikkulam High Value Biodiversity Area (HVBA)

Muthikulam High Value Biodiversity Area (HVBA) is located in Mannarkad Forest Division, which borders the North - western portion of the Western Ghats on the northern side of Palakkad gap in Mannarkad Taluk of Palakkad District. The tract dealt with lies within the north latitude of 10° 14′ and east longitudes between 76° 47′ and 76° 16′. Muthikulam HVBA consists of undulating hills and valleys well clothed with vegetation except for the large grassy area around Muthikulam to the south east and the mass of high hills to the south viz., Elival range. It is a plateau with elevation varying from 610 m at exit of Siruvani to 2,065 m, the highest peak northwest of Elivalmalai. Muthikulam situated at an elevation above 1000 m enjoys salubrious climate with average temperatures not exceeding 22.6^0 C. The average annual daily temperature for the past 30 years is 19.6^0 C and area receives a heavy annual rainfall with total rainfall amounts to 4731mm. The rock formation in Muthikulam area is of Archaean age comprising gneisses and granites. The soil is formed as a result of weathering of the ancient crystalline and metamorphic rocks. The soils are kaolinitic in nature, acidic in reaction, highly porous and friable. Based on the revised system of classification of the Forests of India by Champion and Seth (1963), following are the forest types occurring in Muthikulam HVBA:

1. West Coast Tropical Evergreen Forests (1A/C4)
2. West Coast Semi Evergreen Forests (2A/C2)
3. Southern Moist Mixed Deciduous Forests (3B/C2)
4. Southern Montane Wet Temperate Forests (11 A/C1)

In addition to this, grasslands are also represented in Muthikulam HVBA.

The West Coast Tropical Evergreen Forests are found the areas where an annual rainfall of above 3,000 mm and enjoys an annual temperature below 27^{o}C. Very brief dry spell, characterized by occasional precipitation has supported climatic climax vegetation. The top canopy consists of *Cullenia exarillata, Mesua ferrea, Calophyllum polyanthum, Palaquium ellipticum, Toona ciliata, Hopea parviflora, Canarium strictum, Vateria indica, Dipterocarpus indicus, Dysoxylum malabaricum, Dipterocarpus bourdillonii, Persea macrantha, Bischofia javanica, Poeciloneuron indicum*. The middle canopy consists of trees like *Schleichera oleosa, Cinnamomum*

malabaricum, Myristica malabarica, Elaeocarpus serratus, Hydnocarpus pentandra, Evodia lunu-ankenda, Holigarna arnottiana, Syzygium cumini, Garcinia tinctoria, Macaranga peltata, Mallotus philippensis, and reed and lianas like *Ochlandra travancorica* and *Calamus gamblei* etc., Herbs and shrubs consist of *Strobilanthes* sp. *Clerodendron viscosum, Olea dioica* and *Glycosmis pentaphylla.* The West Coast Semi evergreen forest type is seen in low and medium elevations in which the top canopy consists of *Dipterocarpus indicus, Bombax ceiba, Polyalthia fragrans, Terminalia bellerica, Stereospermum chelonoides, Tetrameles nudiflora, Alstonia scholaris, Lagerstroemia microcarpa, Spondias pinnata, Albizzia odoratissima, Vitex altissima,* and *Dysoxylum ficiforme.* The middle canopy consists of *Mallotus phillippensis, Bauhinia malabarica, Miliusa tomentosa, Bridelia crenulata, Hydnocarpus pentandra,* and *Wrightia tinctoria*. In the Southern Moist Mixed Deciduous Forests, the component species are *Dillenia pentagyna, Xylia xylocarpa, Dalbergia latifolia, Syzygium cumini, Tectona grandis, Lagerstroemia microcarpa, Grewia tiliifolia, Terminalia paniculata, Anogeissus latifolia, Bridelia crenulata, Albizzia lebbeck, Haldina cordifolia, Strychnos nux-vomica, Bambusa bambos, Ochlandra travancorica* etc. The Southern Montane Wet Temperate Forest type is characterized by dense growth of trees in the depressions and folds of the Ghats surrounded by extensive areas of grasslands. Grasslands constitute about 80 per cent of such forests and tree shows stunted growth with spreading canopy, twiggy branchlets and foliage of different colours. The rainfall is above 3,000 mm per annum and altitude above 1500 m. The grass lands are interspersed with Montane Temperate Forest and Sub Tropical Hill Forests. The grass lands are found in upper reaches above 1500 m and the grasses are stunted and carpet like. Though the rainfall is very high, heavy runoff is observed due to steep slope and they are exposed to strong winds. The important species that inhabit in these areas are *Gaultheria fragrantissima*, *Rhododendron nilagiricum*, with grasses like *Arundinella purpurea, Heteropogon contortus* and *Bothriochloa pertusa* etc. A permanent plot was established on the way to Koodam where there is no indication of disturbance in the recent past (Figure 2.2).

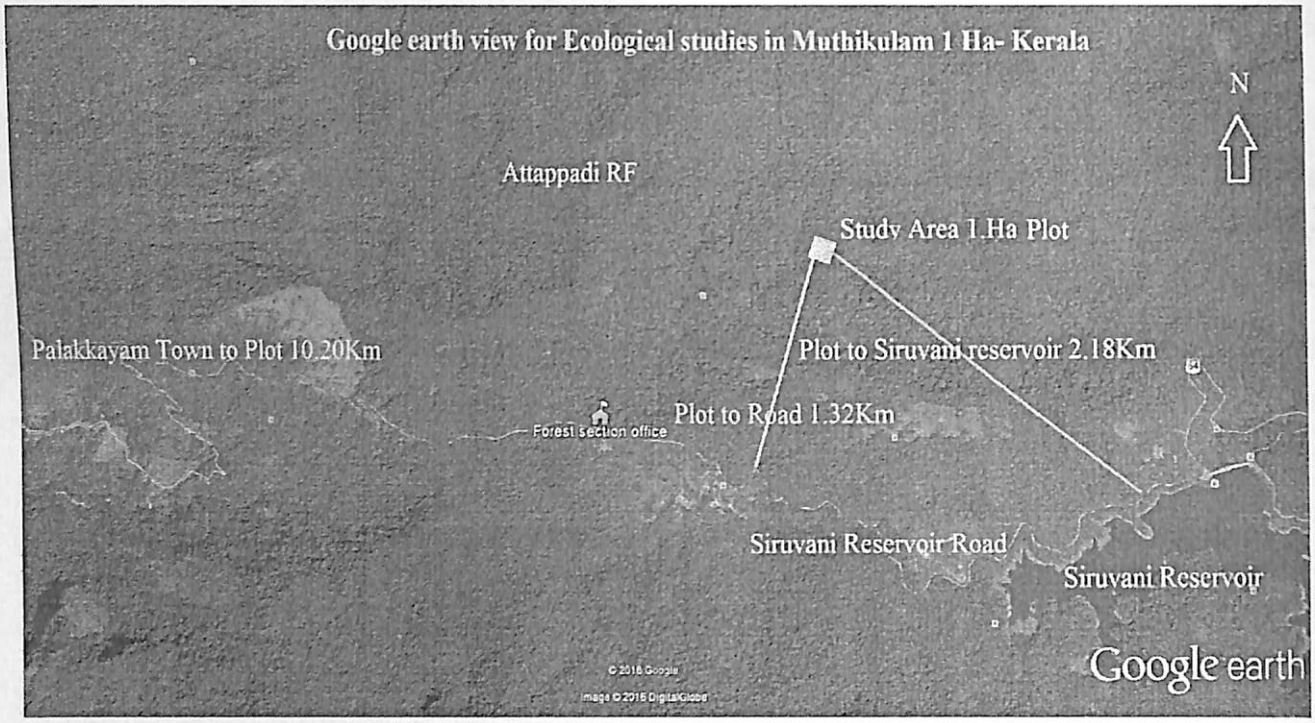


Figure 2.2. Location Map of 1 ha plot at Koodam, Muthikulam HVBA.

Tropical evergreen forests of Vazhachal High Value Biodiversity Area (HVBA)

Vazhachal forests are situated in the Western slopes of the Western Ghats and the altitude varies from 200 m to 1300 m, the highest point being Karimalagopuram in Sholayar Range. The whole area is hilly and undulating, the eastern portion being more rugged than western. The tract dealt with falls between 10° 14′ and 10° 23′ North latitudes and 76° 25′ and 76° 54′ East longitudes. Geologically the area consists of crystalline rocks of archean age of either igneous or metamorphic origin. They comprise chiefly of charnockites, granites, and granitic gneisses with narrow bands of pyroxene granulates and magnetite quartz are most widespread. Many of the hornblende and biotite gneisses are of the nature of charnockites. Different types of soil are met within the Division. It varies from very shallow gravelly soil on the upper slopes to deep, fine - textured soil on the lower slopes and in the valleys. This is due to geological erosion and the resultant alluvial deposition. Alluvial deposits are also met with along the stream and riverbanks. The properties of the soil are further influenced by the type of vegetation cover. The area falls in the tropical zone. The moderate rainfall and humid atmosphere found for the major

part of the year and the comparison of rainfall and temperature shows that the driest period extends for nearly four months. The highest evaporation occurs in March with a second maximum in February in all stations. The dry period starts from December and ends by March/April. The high rainfall supports a wide range of vegetation types which is evident from the bioclimatic conditions. Three distinct seasons are felt in this area viz., cold season, hot season and rainy season. Based on the Revised Forest Types of India by Champion and Seth (1968), the following types of forests are seen in Vazhachal Forest Division.

Group I- Tropical Wet Evergreen Forests: Sub group I A- Southern Tropical Wet Evergreen Forests C- 4 West Coast Tropical Evergreen Forest (IA/C4)

Group II – Tropical Semi-evergreen Forests: Sub group 2A- South Tropical Semi Evergreen Forests C2- West Coast Semi Evergreen Forests (2A/C2)

Group III- Tropical Moist Deciduous Forests: Sub group 3 B- South Indian Moist Deciduous Forests C2- Southern Moist Mixed Deciduous Forests (3B/C2).

The West Coast Tropical Evergreen Forests (IA/C4) cover an extent of 5117.1207 ha occurring in Malakkappara, Thavalakuzhipara, Ambalappara, Sholayar, Karimalagopuram, Anakayam, Karanthodu, Rapra, Charpa, and Sheikalmudi. Dense evergreen forests with lofty trees 45 m or more in height, characterized by large number of species of trees, occurring together - consociations – are rare and ordinarily 2,3 or more, of the upper canopy species individually contributing not more than one percent of the total number. The tree upper canopy species are *Palaquium ellipticum, Cullenia exarillata, Mesua ferrea, Vateria indica, Calophyllum, Lophopetalum wightianum, Holigarna ferruginea, Artocarpus heterophyllus, Dysoxylum malabaricum.* The middle canopy includes *Meliosma simplicifolia, Hydnocarpus macrocarpus, Myristica dactyloides, Bhesa indica, Aglaia lawii, Neloamarkia cadamba, Semecarpus travancorica, Vepris bilocularis, Melicope lunu-ankenda, Drypetes elata, Canarium strictum* etc., The lower canopy dominated by *Ardisia pauciflora, Symplocos laurina, Litsea floribunda, Litsea bourdillonii, Aporusa acuminata, Glochidion ellipticum, Clausena indica, Atalantia racemosa, Agrostistachys borneensis, Phoebe lanceolata.* The main undergrowth are *Laportea crenulata, Sarcococca coriacea, Croton zeylanicus* etc. The climbers like *Diploclisia glaucescens, Sabia malabrica, Embelia ribes, Ancistrocladus heyneanus, Toddalia*

asiatica, Ventilago bombaiensis are also present. The West Coast Semi Evergreen Forest (2A/C2) incluues an Extent covering 13645.65 ha area found in Muthuvarachal, Watchmaram, Mukkumpuzha, Poringal, Manimaruthuthodu, and Oolassery areas. The upper canopy trees are *Calophyllum polyanthum, Dysoxylum malabaricum, Myristica dactyloides, Vateria indica, Dipterocarpus indicus, Kingiodendron pinnatum, Pterygota alata, Gymnacranthera canarica, Mangifera indica, Ormosia travancorica* etc., The middle strata includes *Toona ciliata, Carallia brachiata, Polyalthia fragrans, Elaeocarpus tuberculatus, Elaeocarpus glandulosus, Garcinia morella, Humboldtia vahliana, Holigarna grahamii, Atuna travancorica, Euphoria longan, Vepris bilocularis, Hydnocarpus pentandra, Litsea coriacea, Aporusa lindleyana, Knema attenuata, Walsura trijuga, Vernonia arborea* etc., The lower Canopy covers trees like *Drypetes oblongifolia, Callicarpa tomentosa, Ixora arborea, Xanthophyllum arnottianum, Blepharistemma serratum, Orophea uniflora, Alangium salvifolium, Glochidion zeylanicum, Meiogyne ramarowii, Hunteria zeylanica, Isonandra Ianceolata, Symplocos macrocarpa* etc. The main under growth consists of *Amomum muricatum, Glycosmis pentaphylla, Laportea crenulata, Thottea siliquosa, Schumannianthus virgatus, Pellionia heyneana* etc. The common climbers are *Caesalpinia cucullata, Entada rheedei, Ventelago bombaiensis, Ancistorcladus heyneanus, Derris brevipes* etc. The Southern Moist Mixed Deciduous Forests (3B/C2) with an area of 22631.6221 ha, are leafless condition during the dry season, i.e., from January to March. However, most of the species start flushing before the onset of rains. They occur both on the lower slopes and on ridges on lateritic areas and loamy soils. The common top canopy species are *Albizzia odoratissima, Alstonia scholaris, Bombax malabaricum, Grewia tiliifolia, Miliusa tomentosa, Terminalia crenulata, Xylia xylocarpa* etc. The lower canopy consists of species like *Bridelia retusa, Careya arborea, Cassia fistula,* etc. *Acacia sinuata, Caesalpinia bonducella* etc. are the main climbers in this type. The riparian vegetation along the Chalakudy river system offers a unique ecosystem. Further, it serves as a link between the varied habitats at lower and higher elevations. Healthy riparian zones maintain the channel form and serve as important filters of light, nutrient and sediment which provide habitats for fish and other riverine organisms, function as corridors for their movement, control river temperatures and maintain

bank stability. The riparian forests of the Chalakudy River have revealed the existence of a thick riparian vegetation of more than 10 m width for a distance of 10.5 km downstream from Poringalkuthu, covering an area of 58.5 hectares. Out of this, 26.4 hectares lie within the Vazachal area, including three large islands densely covered by riparian forests. A permanent plot was established on the way to Vazhachal where there is no indication of disturbance in the recent past (Figure 2.3).

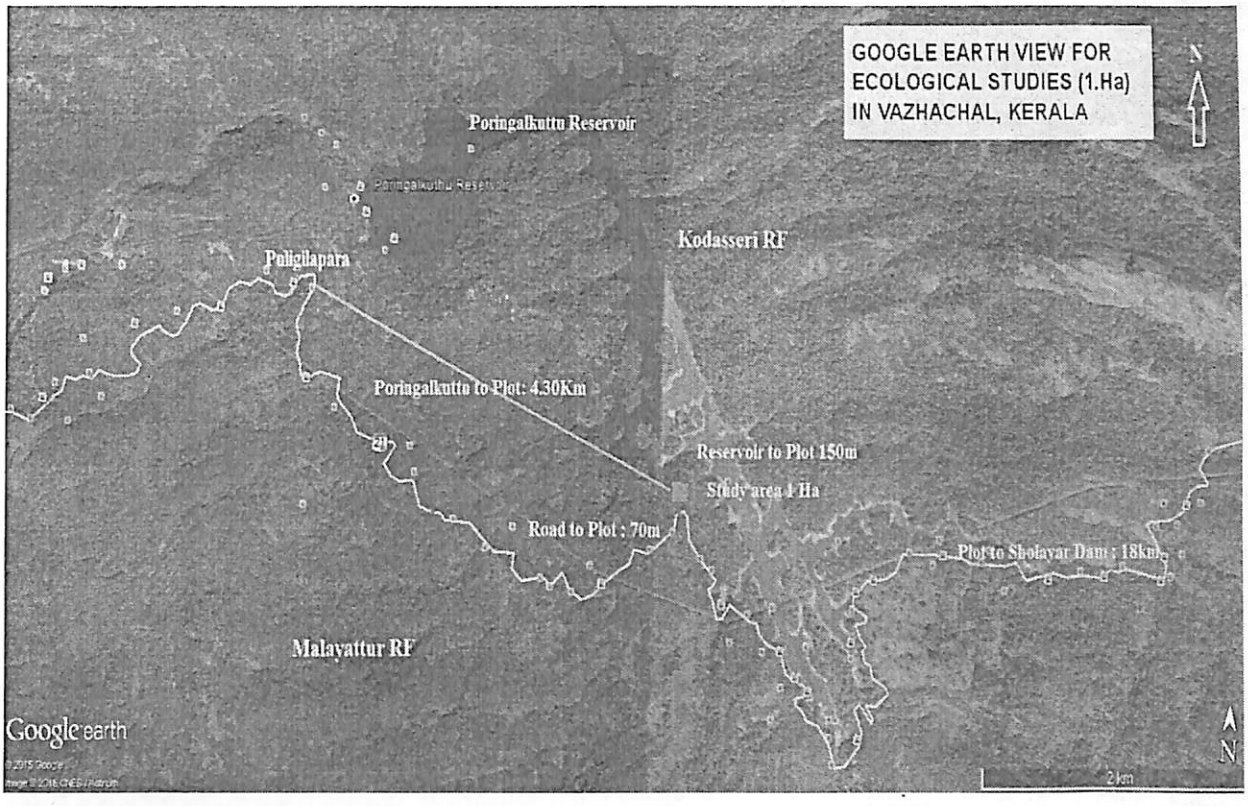


Figure 2.3. Location Map of 1 ha plot at Vazhachal HVBA.

Tropical evergreen forest at Silent Valley National Park

Silent Valley National Park is situated in Palghat district of Kerala State and located at 11° 3' to 11° 13 N latitude and 76° 21' to 76° 35' E longitude. The National Park area is 89.52 km^2 and forms part of the westerly sloping Silent Valley-New Amarambalam basin. The altitude varies between 658 to 2383 m. The mean annual temperature is 20.2^0 C. April and May are the hottest seasons of the year when the mean temperature goes up to 23.5^0 C. December, January and February are the coolest when mean temperature is around 18^0 C. A maximum of 30^0 C and an

absolute minimum of 8^0 C have been recorded. From June to December relative humidity is consistently high often around 95%. The mean annual rainfall is about 4400 mm spread over both south-west and north-east monsoons. The vegetation is of west coast tropical evergreen type. The highly diverse flora of Silent Valley consists of 966 species belonging to 134 families and 559 genera (Manilal, 1988) which comprises 701 dicotyledons and 265 monocotyledons. Relative abundance of certain species in specific patches has resulted in the formation of certain tree association which is a unique feature of the Silent Valley ecosystem. Aiyar (1932) recognized six distinct tree associations and they are: - i) *Cullenia exarillata-Palaquium ellipticum* ii) *Palaquium ellipticum-Mesua ferrea* iii) *Mesua ferrea-Calophyllum elatum* iv) *Palaquium ellipticum - Poeciloneuron indicum* v) *Calophyllum elatum - Ochlandra* sp. vi) *Poeciloneuron indicum - Ochlandra* sp. The vegetation exhibits considerable variations in the floristic composition, physiognomy etc., mainly due to climatic, edaphic and altitudinal variations. Four types of vegetations are recognized viz., a) West Coast Tropical Evergreen forests; b) Subtropical Broad leaved Hill forests; c) Southern Montane Wet Temperate forests d) Southern subtropical savannahs and e) Montane wet grasslands. For establishing 1 ha permanent plot, relatively undisturbed forest patch is selected.

Moist deciduous forest at Parambikkulam Wildlife Sanctuary

The sanctuary Parambikulam Wildlife Sanctuary, a part of Anamalai Hills is located immediate south of Palghat gap, exhibits undulating terrain interspersed with dry or moist valleys. The tract dealt with falls between $76^0 35'$ and $76^0 51'$ E longitude and between $10^0 20'$ and $10^0 32'$ N latitude in the Palakkad revenue district of Kerala and has an area of 274 km^2. The altitude of the sanctuary ranges from 440 m at Chalakkudy river basin to 1438 m at Karimalagopuram. The maximum temperature ranges between 24°C to 33°C and minimum 20°C to 25° C. Major part of the sanctuary is along the windward region and receives high rainfall. The average annual precipitation is 1800 mm varying between 1200 mm to 2300 mm. The area gets both the south - west and north - east monsoons, the south - west monsoon being more active. The main geological formations in the area are hornblende - biotite gneisses, garnetiferous - biotitegneisses, charnockites that had been intruded by garnitic-ortho-gyneisses and plagioclase porphyry-dykes. Major

constituents of the rocks are quartz, biotite, orthoclase and plagioclase feldspar. The Sanctuary represents a variety of habitats, both natural and man-made. There are moist deciduous forests to tropical wet evergreen rain forests; semi-evergreen forests appear where moist deciduous forests merge into evergreen forests. In the upper reaches of Karimalagopuram and Vengoli hills above 1000 m there are natural grasslands. The man made habitats are mostly plantations of teak, which have an extent of about 90 km^2 introduced in the year of 1912. Based on Champion and Seth (1968), the natural vegetation is classified broadly as West-Coast tropical evergreen (55 km^2), West-Coast semi evergreen (20 km^2), the South Indian moist deciduous (65 km^2), and the South Indian dry deciduous (15 km^2) forests. Following Chandrasekharan (1962) and Champion & Seth (1968) the natural vegetation of the sanctuary can be broadly classified into the following types.

West coast tropical evergreen forests: West coast tropical evergreen forests are also found within the moist deciduous forests in places such as Parambikulam, Vengoli, Karianchola and Pulikkal. The important tree associations at higher altitudes are *Mesua-Cullenia-Calophyllum*, *Palaquium-Calophyllum*, *Mesua-Cullenia* and *Palaquium-Mesua*. But at lower altitudes *Vateria-Calophyllum* and *Hopea-Diospyros* associations are prevailing. The common climbers are: *Acacia sinuata*, *Artabotrys zeylanicus*, *Derris brevipes*, *Desmos lawii*, *Entada rheedei*, *Strychnos colubrina*, *Ventilago bombaiensis*, etc. The Montane forests or '*Pseudo sholas*' are unique montane vegetation occupying temperate habitats in tropical latitude and are regarded as relectual communities restricted to valleys and depressions especially along the folds of hills. These types are restricted to Karimala hills and Pandaravarai are not true shola patches. Common species are *Cinnamomum sulphuratum*, *Euonymus indicus*, *Ligustrum perrottetii*, *Maesa indica*, *Symplocos cochinchinensis*, etc. The common epiphytes are *Lycopodium phlegmaria*, *Huperzia phyllantha*, *Bulbophyllum fischeri*, *Eria reticosa*, *Impatiens parasitica*, *Oberonia* spp., *Dendrobium* spp., *Peperomia tetraphylla*, etc.

West coast semi-evergreen forests: West coast semi-evergreen forests type is dominated with evergreen trees and found in Vengoli, Karimala and Orukomban Ranges where felling of evergreen trees has been carried out in the past. Common trees are *Actinodaphne malabarica*, *Schleichera oleosa*, *Xanthophyllum*

arnottianum, *Atuna travancorica*, *Tetrameles nudiflora*, *Bombax insigne*, *Litsea* spp., *Heritiera papilio*, *Cinnamomum malabatrum*, *Bischofia javanica*, *Lagerstroemia microcarpa*, *Garcinia gummi-gutta*, *Elaeocarpus serratus*, *Syzygium cumini*, *Ixora brachiata*, *Chukrasia tabularis*, *Hydnocarpus pentandra*, etc.

Southern moist mixed deciduous forests: Moist deciduous forests in the sanctuary exhibit marked differences with respect to species composition from the western side to the east. These forests are well known for valuable timber yielding species including teak. Substantial moist deciduous forests in Parambikulam and Sungam valley were clear felled. The Kannimara Teak in the moist deciduous forests of Parambikulam is regarded as one of the largest teak in the world. The important tree associations are *Terminalia-Schleichera-Lagerstroemia*, *Bombax - Terminalia* and *Anogeissus-Tectona-Dalbergia*. *Pterocarpus-Tectona*. Towards the eastern side the dominant trees are *Anogeissus latifolia*, *Cleistanthus collinus*, *Shorea roxburghii*, *Madhuca indica*, *Holoptelea integrifolia*, *Semecarpus anacardium*, *Lannea coromandelica*, *Cassine glauca*, etc. Thorny species like *Zizyphus* and *Catunaregam* are the dominant undergrowth here.

Southern dry mixed deciduous forests: Very small area around Kuchimudi and along the eastern slopes of Pandaravarai is covered by dry deciduous forests. *Anogeissus latifolia* is the dominant tree and other trees are *Tectona grandis*, *Givotia molucanna*, *Pterocarpus marsupium*, *Cleistanthus collinus*, *Strychnos potatorum*, *Premna tomentosa*, etc. Trees like *Schrebera swietenioides*, *Heterophragma roxburghii* are sparsely distributed along the rocky slopes.

Southern tropical thorn forests: A small extent of area at Keerappadi in Sungam Range, which is the continuation of Coimbatore plateau is composed of this forest type. Areas have some degree of Eucalyptus coppice growth. *Prosopis juliflora* is the common species. *Capparis sepiaria*, *C. grandis* and *Catunaregam spinosa*, *Carissa spinarum*, *Tarenna asiatica* are the other dominant species in the area.

Vayals: The presence of marshy lands also known as 'Vayals' are unique feature of the sanctuary. They are generally low lying depressions with a high content of clay in the soil where grasses and sedges are the important components. Vayals accumulate running water during monsoon and this becomes stagnant as the dry season approaches. Trees like *Terminalia paniculata*, *T. elliptica*, *Careya arborea*,

Mitragyna parviflora, *Haldina cordifolia*, *Tectona grandis*, *Lagerstroemia microcarpa*, *Butea monosperma*, etc., are getting established in the fringes of vayals. *Axonopus compressus*, *Paspalum* spp., *Eragrostis* spp., *Lipocarpha chinensis*, *Fuirena umbellata*, *Fimbristylis* spp., *Cyperus* spp., etc. grow profusely in these marshy areas. These marshlands are interspersed within the sanctuary in more than 30 places occupying 150 ha. One ha plot was established at Kallippara, Parambikulam Wildlife Sanctuary (Figure 2.4).

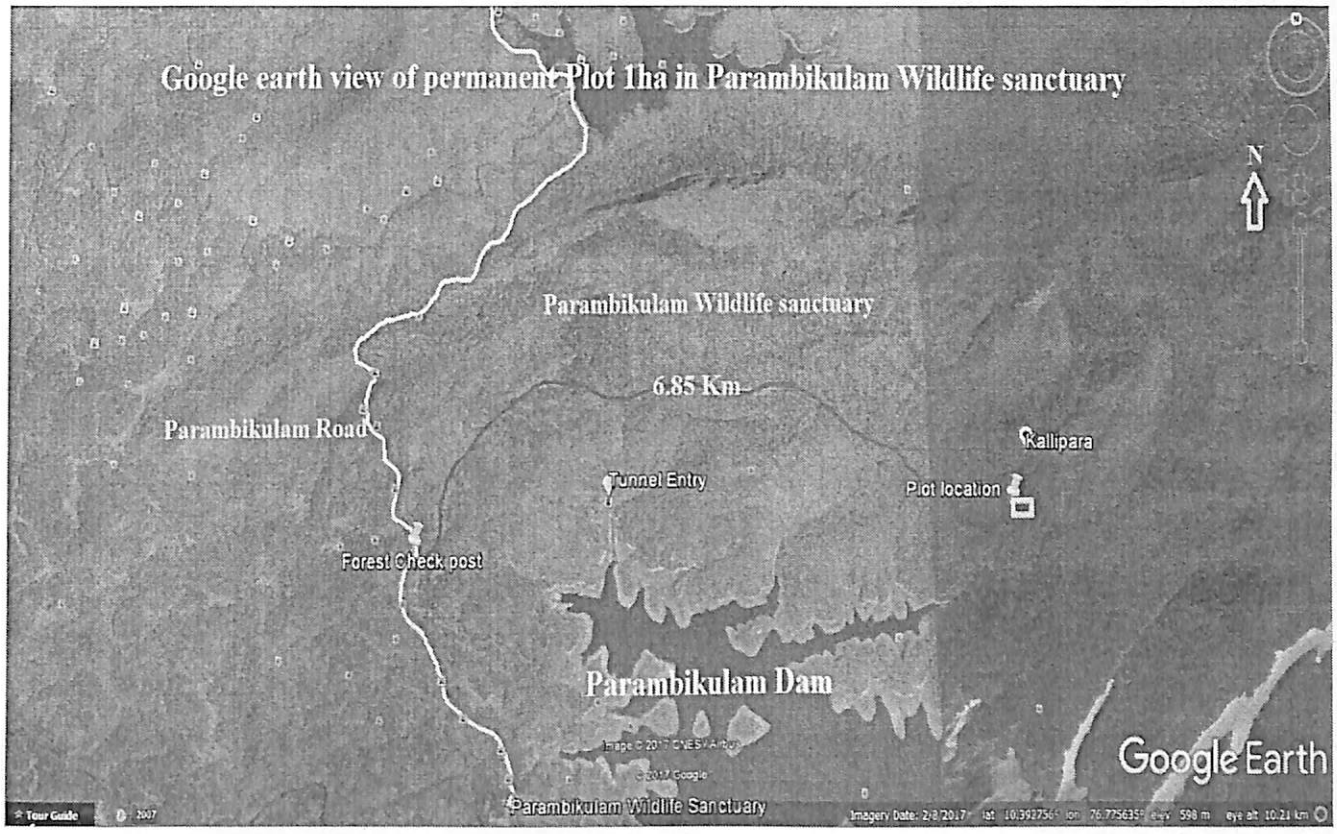


Figure 2.4. Location Map of 1 ha plot at Kallippara, Parambikulam Wildlife Sanctuary

Dry deciduous forest at Chinnar Wildlife Sanctuary

Chinnar Wildlife Sanctuary is located in the rain shadow region of the Western Ghats between 10° 15' to 10° 22' N latitude and 77° 05' to 77° 17' E longitude and comprising an area of 90.44 km^2 under Devikulam Taluk of Idukki district, Kerala State. The East flowing Pambar and its tributaries drains the area. Before it leaves

the Kerala State, Pambar is joined by Chinnar river. River Pambar and its main tributaries are perennial as they originate from the evergreen sholas in the higher reaches of the ghat in the southern and western sides. The sanctuary experiences prolonged hot season and much less rainy days and the annual rainfall ranges from 500 to 800 mm with a minimum and maximum temperature of 12°C and 36° C respectively. The maximum rainfall occurs only in the upper reaches of the ghats from where the Pambar river and its major tributaries originate, making them perennial even during the dry season. The vegetation of the Sanctuary is highly disturbed due to anthropogenic pressures and is dry, deciduous scrub with xerophytic species dominating with interspersed grasslands. Sasidharan (1999) reported 965 angiosperm taxa with 578 genera representing 135 families which is approximately 25% of the species of the total estimated flora of Kerala. The Sanctuary is represented with 114 species representing 38 angiosperm families (Sasidharan, 1999). According to Champion and Seth (1968) and Chandrasekharan (1962a, b, c) the vegetation types are Southern tropical thorn forest (scrub jungle) which is mainly found in Chinnar, Champakkad, Chunkam, Nellimedu and on the slopes of Alampetty, Ichampetty, Palapetty, etc. The major species composition in this type is *Capparis* spp., *Acacia* spp., *Euphorbia* spp., *Opuntia* spp., *Ziziphus* spp., *Grewia* spp., *Albizia amara, Atalantia monophylla. Dichrostachys cinerea, Diospyros cordifolia etc.* The Southern dry mixed deciduous forest is dominated by hardwood deciduous tree species and is mainly found in Puthukkudy, Ichampetty, Thayanankkudy, Palapetty, Alampetty, Karimalai areas. The major species representing the forest type are *Canthium coromandelicum, Shorea roxburghii, Hardwickia binata, Boswellia serrata, Santalum album, Cassia fistula, Sterculia urens, Chloroxylon swietenia, Sapindus emarginatus, Tarenna asiatica, Dodonaea* spp. etc. The another type, Southern moist mixed deciduous forest is mainly found in Alampetty, Ichampetty, Karimalai, Puthukkudy, Palapetty areas and the major vegetation is *Gmelina arborea, Pterocarpus marsupium, Grewia tiliifolia, Schleichera oleosa, Wrightia tinctoria, Bridelia crenulata. Buchanania lanzan, Stereospermum colais, Albizia odoratissima* etc. The Tropical riparian fringing forest is also found on the sides of streams of *Pambar* and *Chinnar* rivers is characterized by *Homonoia riparia, Hopea parviflora, Schefflera racemosa, Entada rheedei, Bischofia*

javanica,Terminalia arjuna, Careya arborea, Emblica officinalis, Sapindus laurifolia, Mallotus stenanthus, Drypetes roxburghii, Vitex leucoxylon, Pongamia pinnata, Garcinia gummi-gutta, Calophyllum calaba, Lepisanthes tetraphylla, Syzygium cumini etc. are included in this type. The Southern montane wet temperate forest is found at an altitude above 1300 m asl in Olikkudy shola and Kariveppinshola which are represented by the tree species like *Agrostistachys indica, Syzygium* spp. *Elaeocarpus recurvatus, Litsea* spp., *Actinodaphne malabarica, Fagraea ceylanica, Cryptocarya anamallayana, Calamus gamblei, Pittosporum* spp., *Gordonia obtusa, Mallotus tetracoccus, Aglaia elaeagnoidea, Microtropis parviflora, Meliosma pinnata, Ardisia pauciflora, Cinnamomum verum, Ficus amplocarpa,* etc. In the Southern montane wet grassland type, the predominant species representing this type of vegetation are *Arundinella* spp., *Cymbopogon flexuosus, Ischaemum nilagiricum, Setaria pumila, Themeda triandra, Echinochloa colona, Digitaria wallichiana, Chrysopogon zeylanicus* etc. The location for one ha plots at Chinnar WLS is at Champakkad (Figure 2.5)

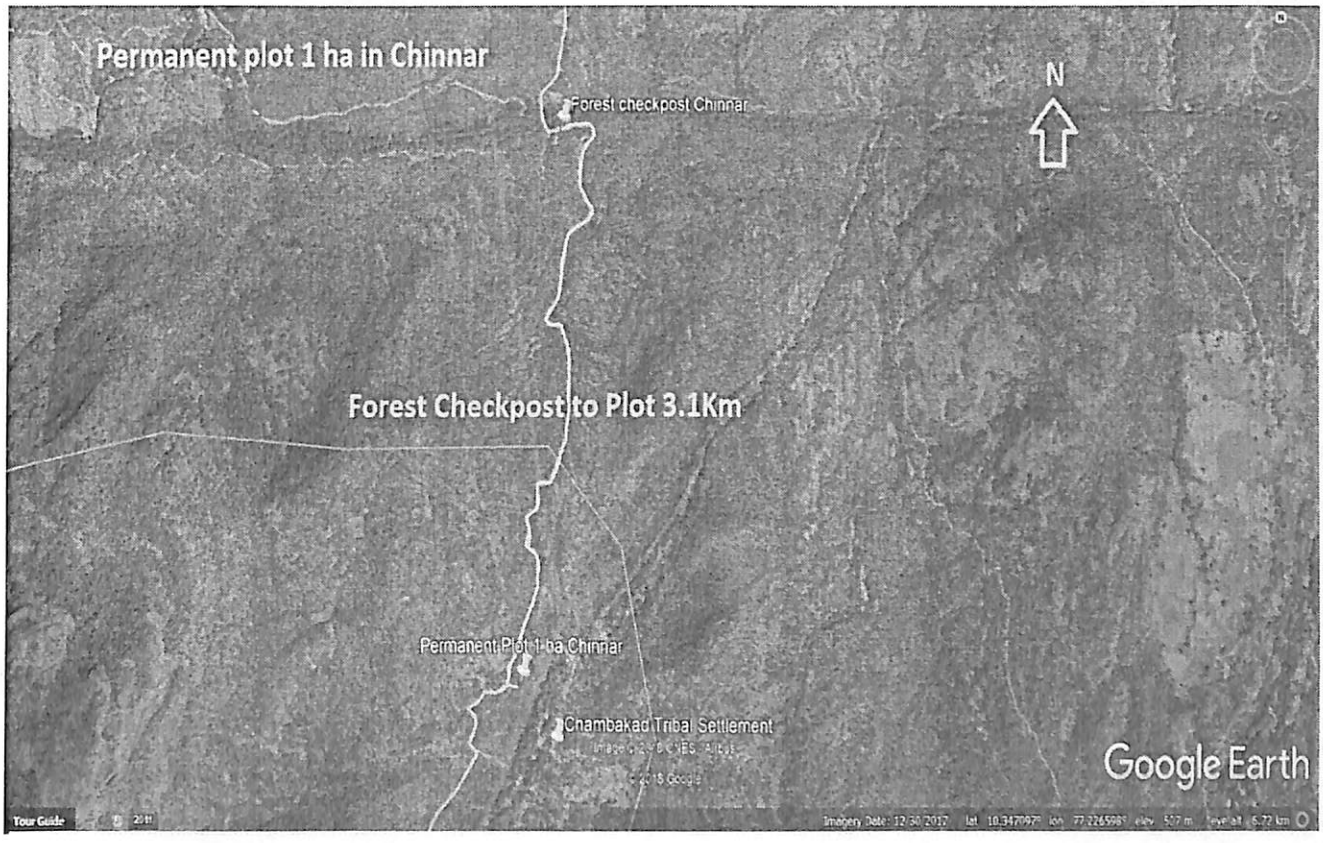


Figure 2.5. Location Map of 1 ha plot at Champakkad, Chinnar Wildlife Sanctuary

Establishment of permanent sample plots

The estimates of species diversity and richness are higher when many small plots are sampled, as compared to a few but larger plots (Whitmore *et al.*, 1985). But compared to small plots, large plots also have their advantages: a more diverse representation of life forms; the gradient of species commonality and rarity become apparent; site monitoring of dynamic changes in the ecosystem can be undertaken continuously (Herben, 1996). The minimum size for a permanent plot should be 1 hectare and the species diversity and dynamic processes are poorly estimated in plots smaller than this. 1 ha plot can be progressively divided into subplots of 10 x 10 m subplots (or quadrats) with rope and pegs, using tape and compass. If necessary for the study (seedlings count, ground cover, etc.), quadrats of 5 x 5 m can also be laid within the 10 x 10 m subplots.

For establishing 1-ha plots in different ecosystems, the detailed methodology followed by Chandrashekara *et al.*, (1998) was followed. In each sites, 1-ha plots were marked and which in turn subdivided into 100 quadrats 10 m x 10 m in size (Figure 2.6). The surveying to establish quadrat corners was proceeded from the baseline of the plot. For this at first, a baseline of 100 m was established in a given direction. Ten points, each at an interval of 10 m were marked on the baseline. At each such point a peg was fixed and from each point, measured a distance of 10 m perpendicular to the baseline. However, before fixing pegs at each new point measurements were made to confirm that the distance between two adjacent points was 10 m and that the 2nd line passing through 10 new points was horizontal to the baseline. Thus a row of ten quadrats was established. The next step was to repeat the same process by considering the new line as the baseline to establish remaining 90 quadrats. As the establishment of corners proceeded three measurements namely the back measurement (from the new set up point back to the previous stake on the same line), the 'check measurement (to previous established stakes below the current line), and the 'new' measurement (to set next stake on the current line) were made to ensure that the size of each quadrat was 10 m x 10 m. Once the corners of all 100 quadrats were established, the quadrats were permanently marked at each of their corners with survey stones fixed to the ground. All corner stones well above the forest floor were painted to increase the

visibility and each corner stone is labelled with a number to differentiate its location in the plot. In each permanent plot, a name board to indicate the type of forest, area and year of establishment of the sample plot was fixed.

Tree diversity analysis

Tree species diversity and regeneration pattern in permanent plots in the plot established, a rope was tied along the border of each quadrat. In each permanent plot tree tagging and identification was carried out in different stages. In the first stage, all trees above 30.1 cm girth at breast height (gbh; measured with tape at 1.37 m from the ground) were considered which were categorized as mature trees. In each of 100 quadrats mature trees were located and tagged with the numbered aluminium label facing towards the baseline. Tags were fixed above 1.37 cm level to avoid interference with gbh measurement. Each tree was identified and recorded the number allotted to it, and its gbh. For the trees with large buttresses, girth was measured just above the level of buttress. The line of gbh measurement was marked with paint. Conditions of all labeled trees were assessed and categorized them into alive-undamaged and alive-damaged. Causes for damage were also recorded. These data were collected for reuse in recensuses or following cataclysmic events. In the second stage of tree tagging and identification, all trees with gbh ranging from 10.1 cm to 30.0 cm were considered and they were designated as saplings. Tagging, gbh measurement, identification and assessment of tree conditions followed the methods already discussed. However, the number of quadrats to be sampled for the saplings was determined using species-area curve (Misra, 1968). Most of the trees species were identified in the field while others were identified with the samples collected and referring the herbaria. Herbarium voucher specimens collected were deposited at KFRI herbarium. The total number of stems per hectare was estimated separately for mature trees, saplings and tree seedlings. Similarly, basal area of all stems of a species in mature tree and saplings categories was also calculated. In the case seedlings, basal area was not calculated, as the exact girth of individuals seedlings was not recorded. Formula used to calculate the relative density, relative frequency and relative dominance and the importance value index (IVI) are following:

$$\text{Relative density} = \frac{\text{total number of individuals of a species x 100}}{\text{total number of individuals of all species}}$$

$$\text{Frequency} = \frac{\text{number of quadrats in which a species found}}{\text{number of quadrats studied}}$$

$$\text{Relative frequency} = \frac{\text{frequency of a Riven species X 100}}{\text{sum of frequency of all species}}$$

$$\text{Relative dominance} = \frac{\text{total basal area of a given species X 100}}{\text{total basal area of all species}}$$

Importance value Index (IVI) of a species = sum of relative density, relative dominance and relative frequency

However, in the case of seedling population, IVI was calculated as the sum of relative density and relative frequency. Species diversity was calculated using a formula given by Margalef (1968) as:

$$H = - \Sigma [(n, / N) \log2(ni/IN)]$$

where H = Shannon index of species diversity, n,= number of individuals of species i, N= total number of individuals of all species in the community. The index of dominance of the community was calculated by

Simpson's index (Simpson, 1949) as: $C = \Sigma (ni/N) 2$

where C= index of dominance; n, and N being the same in the Shannon index of general diversity.

Figure 2.6. One ha plot divided in to 10 x 10 quadrats.

10	11	30	31	50	51	70	71	90	91
9	12	29	32	49	52	69	72	89	92
8	13	28	33	48	53	68	73	88	93
7	14	27	34	47	54	67	74	87	94
6	15	26	35	46	55	66	75	86	95
5	16	25	36	45	56	6 5	76	85	96
4	17	24	37	44	57	64	77	84	97
3	18	23	38	43	58	63	78	83	98
2	19	22	39	42	59	62	79	82	99
1	20	21	40	41	60	61	80	81	100

3.0. RESULTS AND DISCUSSION

3.1. TREE SPECIES DIVERSITY AND STAND STRUCTURE

3.1.1. Vaguvarai (Eravikulam National Park)

A description of the mature trees and saplings present in the Vaguvarai plot in Eravikulam National Park is presented in Table 3.1. Among mature tree population, *Symplocos macrophylla, Syzygium densiflorum, Gomphandra coriaceae, Aporosa fusiformis* and *Garcinia cowa* are the first five dominant species. Tree sapling population is dominated by *Glochidion neilgherrence* followed by *Chionanthus ramiflorus, Symplocos macrophylla, Neolitsea scrobiculatus* and *Apollonias arnottii*. The studies done by Swarupanandan *et al.*, (1998) on two major chunks of the shola forests, the Mannavan shola and the Eravikulam National Park identified the most dominant tree species as *Cinnamomum wightii, Litsea* sp., *Mastixia arborea, Hydnocarpus alpina, Isonandra candolleana, Persea macrantha, Syzygium* sp. and *Gomphandra coriacea*.

Compared to shola forest situated at Kurunjalu in Chikmagalore District in the Western Ghat part of Karnataka where the number of tree species encountered was 20 (Swamy, 1988), the Vaguvarai shola plot is richer in terms of species richness as similar to Mannavan shola (Chandrasekhara *et al.*, 1998). The stem density recorded in the present study is almost similar to Kurunjalu (Swamy, 1988) as 235 (saplings), 475 (mature trees), but low in compared to Mannavan shola (Chandrasekhara *et al.*, 1998) where it was 818 (saplings) and 566 (mature trees). The species diversity in the present study (Table 3.2) is also quite lower in compared to Kurunjalu shola (H = 3.612; Swamy, 1988) and Mannavan shola (H = 3.997; Chandrasekhara *et al.*, 1998). According to Swarupanandan *et al.*, (1998), the per hectare density of trees ≥10 cm dbh in the shola forests is comparable to that of the evergreen forests whereas the density increases with elevation, the basal area decreases, indicating a reduction in tree size with elevation. Chandrashekara and Muraleedharan (2001) had conducted studies of the impact of disturbances on vegetation structure, composition and regeneration pattern, to identify the socio-economic reasons for disturbances and to evolve strategies for

management of different shola patches of Mannavan Shola, Pullaradi Shola, Manthan Shola and Aruvikkad Sholas. The study identified *Hydnocarpus alpina*, *Isonandra stocksii* and *Gomphandra coriacea* as the dominant species in mature tree phase in undisturbed areas, whereas in disturbed sites, light demanding species like *Symplocos cochinchinensis* and *Daphniphyllum neilgherrense* dominate contributing about 50 % to the total IVI of the mature trees. The disturbance in the Mannavan shola is leading to the invasion of exotic Acacias such as *Acacia dealbata* and also *Acacia melanoxylon*. Cattle grazing, lemongrass cultivation, firewood collection, timber collection, and shifting cultivation are the major degradation for Vaguvarai shola and this might be gradual reduction in structure and diversity composition when compared to the other shola patches of the Western Ghats. There is a suggestion to constitute a shola forest reserve (Rodgers and Panwar, 1988) which is very valuable when realize the fact that in many places plantations have been actively colonized by natural shola forest species. The fragmentation of shola patches are either due to anthropogenic or natural factors like fire, frost, wind etc.. According to Meher-Homji (1969) the destruction of shola forests leads to scrub savanna which, on further degradation, gives rises to grasslands and ultimately to barren rocks. Chandrasekharan (1962) pointed that the grasslands in the high ranges had been reclaimed by planting Wattle and Eucalypts on a large scale. Plantations of *Acacia mearnsii* and Eucalypts were raised in certain areas of southwest region of Pettimudi and southeast region of Vaguvarai. The establishment of monoculture plantations in the high ranges gradually reduced forest cover\bout 50% to that the beginning of this century. Of this 82% were contributed by monoculture of teak, eucalyptus and wattle (Basha, 1990). An important feature of Black Wattle is that it spreads very quickly in burnt areas (Karunakaran et al., 1997). Urgent intervention is needed to replace these patches by developing suitable site specific eco-restoration protocols.

Table 3.1. Density of (Individuals ha^{-1}) and importance value index (IVI) of mature trees (gbh ≥ 30.1 cm) and saplings (gbh 10.1 cm to 30.0 cm) in the permanent plots established at Vaguvarai.

Species	Mature trees		Saplings	
	Density	IVI	Density	IVI
Actinodaphne bourdillonii	2	1.33	--	--
Aglaia apiocarpa	1	0.68	2	1.51
Apollonias arnottii	6	3.56	23	19.37
Aporosa fusiformis	31	20.94	3	3.05
Beilschmiedia wightii	8	5.12	12	10.76
Bhesa indica	1	0.65	1	1.18
Canarium strictum	3	2.28	--	--
Celtis tetrandra	1	0.87	--	--
Chionanthus ramiflorus	18	12.25	30	28.49
Cinnamomum sulphuratum	2	1.91	--	--
Cinnamomum wightii	26	17.18	3	2.85
Elaeocarpus recurvatus	5	3.94	--	--
Garcinia cowa	23	18.43	5	4.76
Glochidion neilgherrence	29	15.44	34	34.37
Gomphandra coriacea	46	27.57	17	18.82
Ilex gardneriana	23	17.05	16	15.58
Isonandra perottetiana	12	8.14	6	5.40
Litsea glabrata	8	5.58	18	15.90
Litsea oleoides	--	--	10	8.53
Microtropis ramiflora	19	13.72	19	18.49
Neolitsea scrobiculatus	25	16.97	23	23.19
Nothapodytes nimmoniana	3	2.01	6	4.94
Persea macrantha	1	0.50	10	12.33
Psychotria truncata	3	1.51	4	3.97
Rhododendron arboreum	--	--	2	2.64
Saprosma foetens	11	6.92	3	2.38
Schefflera capitata	5	4.63	--	--
Scolopia crenata	9	5.79	3	2.95
Symplocos macrophylla	45	35.03	30	27.29

Syzygium densiflorum	28	32.35	1	1.21
Syzygium lanceolatum	3	1.67	1	0.81
Unidentified -1	10	5.13	4	3.84
Unidentified -2	1	0.62	22	19.07
Unidentified -3	5	3.37	3	3.26
Unidentified -4	6	3.76	2	2.17
Xanthophyllum arnottianum	5	2.94	1	0.75

Figure 3.1. Girth class distribution of individuals in the permanent plot established at Vaguvarai, Kerala.

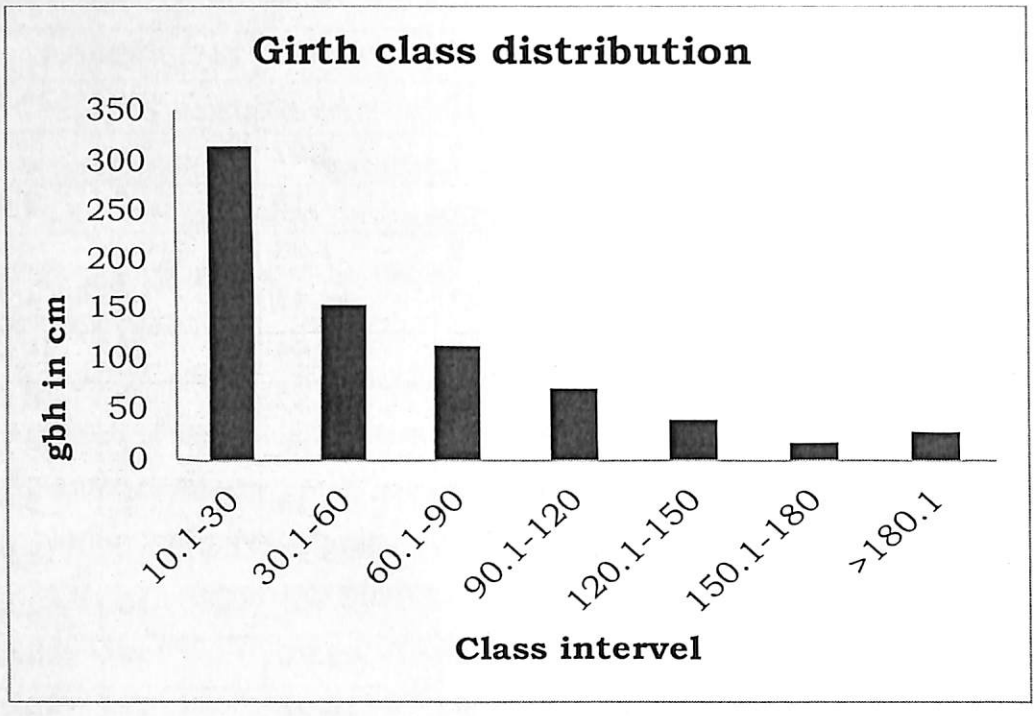


Table 3.2. Basic statistics of mature trees (gbh> 30.1 cm), saplings (gbh 10.1 cm to 30.0 cm) populations in the permanent plots at Vaguvarai, Kerala.

Titles	Phases	
	Mature trees	Saplings
Families represented	18	14
Species represented	34	30
Total number of individuals ($ha^{-1)}$	423	315
Total number of basal area (m^2 $ha^{-1)}$	34.38	0.901
Species diversity index (H)	3.068	2.966
Species dominance value (C)	0.056	0.06

The size-class distribution of individuals has been used to understand regeneration, disturbances and future stability of tree species in forest communities (Pandey, 2006). The figure 3.1 and Table 3.3 shows the Girth class distribution of individuals in the permanent plot. Analysis of comparison of girth class distribution of all species in the plot indicated that the dominant species like *Chionanthus ramiflorus, Symplocos macrophylla, Neolitsea scrobiculatus* and other species like *Aporosa fusiformis, Cinnamomum wightii, Ilex gardneriana and Syzygium densiflorum* etc., are represented in all girth classes. It has observed that be noted that while 70% species represented mainly in lower girth classes indicates better recruitment and 30% species do not have representation in mature phases which indicates higher anthropogenic disturbances in this area. The dominant species like *Glochidion neilgherrence and Apollonias arnottii* has not represented adequate individual in higler girth classes. The tree species diversity was low for mature tree phase compared to sapling phase. Chandrashekara *et al.* (1998) pointed that the species diversity recorded for mature trees was much lower for shola forests of Mannavan shola. Swarupanandan *et al.*, (1998) reported that regeneration of most of the tree species in Shola patches is fairly well represented, and several species have deficiency in some life stages. The exact reason for the differences in regeneration population in Shola is not known and it might be due to compositional differences exist in the shola forests depending upon the site, and that this in turn reflect upon the population structure in the stands.

Table 3.3. Girth class distribution of trees in the permanent plot established at Vaguvarai

Species	Girth Classes						
	A	B	C	D	E	F	G
Actinodaphne bourdillonii	-	-	1	1	-	-	-
Aglaia apiocarpa	2	-	-	1	-	-	-
Apollonias arnottii	23	4	1	-	1	-	-
Aporosa fusiformis	3	16	5	3	4	1	2
Beilschmiedia wightii	12	6	-	-	1	-	1
Bhesa indica	1	-	1	-	-	-	-
Canarium strictum	-	-	1	1	-	-	1
Celtis tetrandra	-	-	-	-	1	-	-
Chionanthus ramiflorus	30	7	4	4	1	1	1
Cinnamomum sulphuratum	-	-	-	1	-	1	-
Cinnamomum wightii	3	5	12	5	1	2	-
Elaeocarpus recurvatus	-	1	1	-	2	1	-
Garcinia cowa	5	-	4	10	7	2	-
Glochidion neilgherrence	34	23	6	-	-	-	-
Gomphandra coriacea	17	16	23	5	-	-	1
Ilex gardneriana	17	9	4	3	2	2	2
Isonandra perottetiana	6	2	1	9	-	-	-
Litsea glabrata	18	4	-	2	1	-	1
Litsea oleoides	10	-	-	-	-	-	-
Microtropis ramiflora	19	4	7	5	1	-	2
Neolitsea scrobiculatus	23	14	3	4	2	1	1
Nothapodytes nimmoniana	6	2	-	-	1	-	-
Persea macrantha	10	1	-	-	-	-	-
Psychotria truncata	4	3	-	-	-	-	-
Rhododendron arboreum	2		-	-	-	-	-
Saprosma foetens	3	3	3	5	-	-	-
Schefflera capitata	-	-	-	1	2	2	-
Scolopia crenata	3	6	1	-	1	1	-
Symplocos macrophylla	30	8	14	6	9	-	7
Syzygium densiflorum	1	1	6	4	4	3	10
Syzygium lanceolatum	1	2	1	-	-	-	-
UNV 1	4	9	1	-	-	-	-
UNV 2	22	-	1	-	-	-	-
UNV 3	3	-	3	2	-	-	-
UNV 4	2	4	1	-	-	1	-
Xanthophyllum arnottianum	1	1	4	-	-	-	-

*Girth classes: A- Saplings (gbh 10.0 cm to 30.0 cm), B to G - mature trees , 30.1cm - 60.0 cm, 60. cm - 90.0 cm , 90.1 cm - 120.0 cm. 120.1 cm - 150.0 cm, 150.1 cm - 180.0 cm, and >180.1 cm.

In the Appendix 1.1 and Appendix 1.2, the distribution pattern of mature trees, and saplings in different quadrats laid out in the permanent plot are given which will help in recensuses and also to know the impact of any cataclysmic event on the health and survivability of these species.

3.1.2. Chambakkad (Chinnar WLS)

Atlantia monophylla, *Erythroxylum monogynum*, *Strychnos potatorum*, *Commiphora caudata* and *Alphonsea sclerocarpa* are the dominant species in the mature tree phase in the permanent pot established in Chambakkad at Chinnar WLS (Table 3.4). These four dominant species constituted about 39% of the mature tree population. The stand dynamics of dry deciduous forest plot (Chandrashekara *et al.*, 1998) established in the Chinnar Wildlife Sanctuary shows *Chloroxylum swietenia* - *Anogeissus latifolia* - *Strychnos potatoram* type as three dominant species which contributed about 77% of the stem density and with total IVI of 214.17 in the mature tree phase (Table 3.5). Similarly in a study on Alampetty region (Chandrashekara and Jayaraman, 2002) also identified in the same dominance pattern with 67% of the stem density and with total IVI of 185.15 in the tree phase. Totally 24 tree species were recorded from the plot, 19 species showed poor regeneration. Chandrashekara *et al.* (1998) recorded 674 trees ha^{-1} with basal area of 13.97 m^2 ha^{-1} which increased to 744 trees ha^{-1} with basal area of 19.36 m^2 ha^1. In the present study it is 282 trees ha^{-1} with basal area of 16.08 m^2 ha^{-1}.

Table 3.4. Density of (individuals ha^{-1}) and importance value index (IVI) of mature trees (gbh ≥ 30.1 cm) and saplings (gbh 10.1 cm to 30.0 cm) in the permanent plots established at Champakad.

Species	Mature trees		Saplings	
	Density	IVI	Density	IVI
Albizia amara	1	1.97		
Alphonsea sclerocarpa	16	17.71	9	6.82
Anogeissus latifolia	10	8.93	9	6.84
Atlantia monophylla	42	35.79	132	91.74
Azadirachta indica	2	1.75	--	--

Bauhinia malabarica	9	16.64	5	3.71
Canthium coromandelicum	4	4.24	3	2.26
Carissa spinarum	1	0.89	10	7.38
Catunaregam spinosa	13	10.01	24	19.21
Celtis timorensis	10	8.73	11	8.28
Chloroxylon swietenia	10	9.97	13	10.98
Combretum albidum	--	--	1	0.66
Commiphora berryi	8	6.32	--	--
Commiphora caudata	16	22.23	14	10.98
Crataeva adansonii	3	1.99	9	6.98
Dalbergia lanceolaria	1	2.01	--	--
Dalbergia latifolia	4	6.57	1	0.82
Diospyros cordifolia	3	3.56	3	2.05
Diospyros ebenum	8	7.78	6	4.31
Diospyros ferrea	2	1.75	--	--
Diospyros latifolia	5	4.84	11	8.44
Dolichandrone arcuata	5	4.59	1	0.89
Erythroxylum monogynum	22	23.08	22	16.83
Ficus mollis	1	4.81	--	--
Flacourtia montana	1	1.17	2	1.33
Gardenia gummifera	2	1.94	1	0.75
Gardenia spp	1	0.87	-	-
Glycosmis pentaphylla	3	2.31	40	24.11
Gmelina asiatica	1	0.88	2	1.36
Grewia barberi	1	1.09	--	--
Grewia villosa	14	12.69	18	13.92
Ixora brachiata	2	1.93	--	--
Lannea coromandelica	1	0.75	--	--
Pavetta indica	14	14.03	8	6.52
Pleiospermium alatum	6	5.62	13	8.53
Sapindus emarginatus	12	9.65	19	14.81
Schleichera oleosa	5	4.84	1	0.67
Sterculia urens	7	8.44	3	2.33
Strychnos nux-vomica	2	1.52	1	0.66

Strychnos potatorum	20	20.51	20	15.69
Tamarindus indica	1	4.58	--	--
Ziziphus oenoplia	1	0.86	--	--

Figure 3.2. Girth class distribution of individuals in the permanent plot established at Champakad, Kerala.

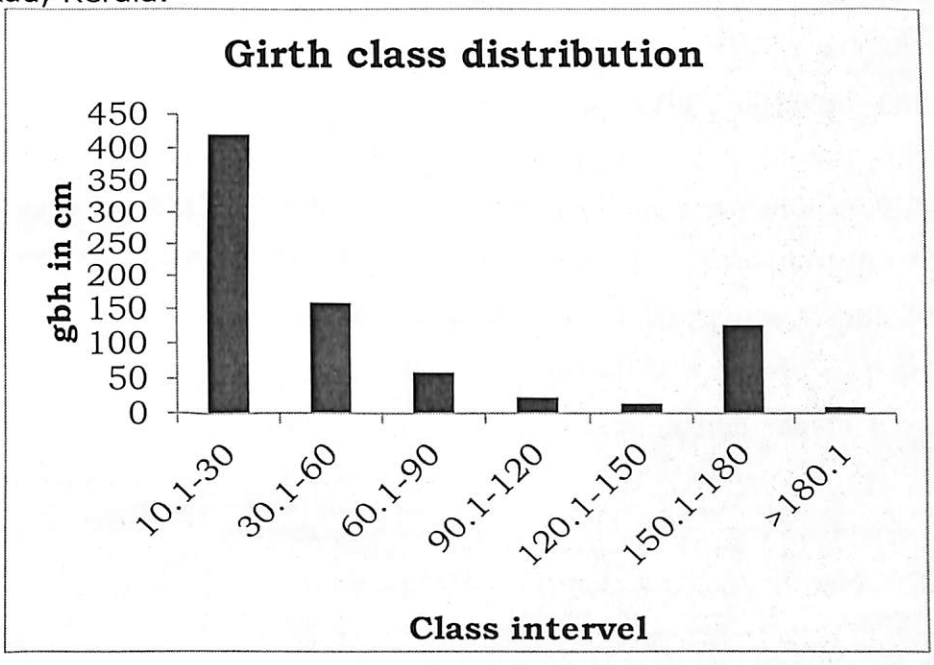


Table 3.5. Basic statistics of mature trees (gbh> 30.1 cm), saplings (gbh 10.1 cm to 30.0 cm) populations in the permanent plots at at Champakad, Kerala.

Titles	Phases	
	Mature trees	Saplings
Families represented	22	18
Species represented	41	30
Total number of individuals (ha^{-1})	282	420
Total number of basal area (m^2 ha^{-1})	16.084	1.321
Species diversity index (H)	3.259	2.65
Species dominance value (C)	0.05	0.128

Analysis of comparison of girth class distribution of mature trees and saplings (Figure 3.2 & Table 3.6) in the plot indicated that majority of the individuals are in gbh 10.1 cm to 30 cm followed by gbh 150.1 cm to 180 cm. Major dominant species are are represented in all girth classes except for *Atlantia monophylla*. The poor representation of trees especially those falling under middle and higher size classes may be attributed to illicit felling for firewood of such trees by the forest dwellers. Sasidharan (1999) reported that the vegetation of the Sanctuary in the past had been severely affected by forest fire especially the scrub and dry vegetation with the long dry season adds much to this cause. Moreover, the shifting of cultivation in the past by the tribes had played a played great role in the destruction of natural forests and the extent of natural forests has been narrowed down. Most of such abandoned cultivated areas are established by weedy and less useful plant such as *Lantana, Chromolaena, Prosopis,* etc.

Table 3.6. Girth class distribution of trees in the permanent plot established a Chambakad.

Species	Girth Classes						
	A	B	C	D	E	F	G
Albizia amara	-	-	-	-	-	1	-
Alphonsea sclerocarpa	9	5	6	3	1	1	-
Anogeissus latifolia	9	5	4	1	-	-	-
Atlantia monophylla	134	30	8	2	-	-	-
Azadirachta indica	-	1	-	1	-	-	-
Bauhinia malabarica	5	3	-	1		2	3
Canthium coromandelicum	3	3	-	-	1	-	-
Carissa spinarum	10	-	1	-	-	-	-
Catunaregam spinosa	26	9	2	-	-		-
Celtis timorensis	11	8		2	-	-	-
Chloroxylon swietenia	13	5	3	1	-	1	-
Combretum albidum	1	-	-	-	-	-	-
Commiphora berryi	-	8	-	-	-	-	-
Commiphora caudata	14	3	4	4	2	1	2
Crataeva adansonii	9	3	-	-	-	-	-
Diospyros latifolia	11	-	-	-	1	-	-
Dalbergia lanceolaria	-	-	-	-	-	1	-
Dalbergia latifolia	1	1	1	-	-	1	1
Diospyros cordifolia	3	2	-	-	-	1	-
Diospyros ebenum	7	3	2	1	1	-	-

Diospyros ferrea	-	1	1	-	-	-	-
Diospyros latifolia	-	3	1	-	-	-	-
Dolichandrone arcuata	1	3	2	-	-	-	-
Erythroxylum monogynum	23	11	4	2	2	1	1
Ficus mollis	-	-	-	-	-	-	1
Flacourtia montana	2	-	-	1	-	-	-
Gardenia gummifera	1	-	2	-	-	-	-
Gardenia spp	-	1	-	-	-	-	-
Glycosmis pentaphylla	40	3	-	-	-	-	-
Gmelina asiatica	2	-	1	-	-	-	-
Grewia barberi	-	-	1	-	-	-	-
Grewia villosa	19	10	1	1	1	-	-
Ixora brachiata	-	1	-	1	-	-	-
Lannea coromandelica	-	1	-	-	-	-	-
Pavetta indica	8	6	5	1	2	-	-
Pleiospermium alatum	13	3	2	1	-	-	-
Sapindus emarginatus	19	8	3	1	-	-	-
Schleichera oleosa	1	1	3	-	-	1	-
Sterculia urens	4	4	-	-	1	-	1
Strychnos nux-vomica	1	2	-	-	-	-	-
Strychnos potatorum	20	12	3	-	3	2	-
Tamarindus indica	-	-	-	-	-	-	1
Ziziphus oenoplia	-	1	-	-	-	-	

*Girth classes: A- Saplings (gbh 10.0 cm to 30.0 cm), B to G - mature trees , 30.1cm - 60.0 cm, 60.1 cm - 90.0 cm , 90.1 cm - 120.0 cm. 120.1 cm - 150.0 cm, 150.1 cm - 180.0 cm, and >180.1 cm.

In the Appendix 1.3 and Appendix 1.4, the distribution pattern of mature trees, and saplings in different quadrats laid out in the permanent plot are given which will help in recensuses and also to know the impact of any cataclysmic event on the health and survivability of these species.

3.1.3. **Silent valley**

Cullenia exarillata, *Palaquium ellipticum*, *Agrostistachys borneensis* and *Myristica malabarica* are the dominant species in the mature tree phase in the permanent pot established in the wet evergreen forest at Silent Valley (Table 3.7). Among these *Cullenia exarillata* and *Palaquium ellipticum* contributed 37% and 16% of the mature tree population. Generally, in the evergreen stands, the association of *Cullenia exarillata* - *Mesua ferrea* - *Palaquium ellipticum* type is the most important

among the medium elevation forest types in the Western Ghats, both in area and quality (Pascal, 1988). The studies on stand dynamics of evergreen forests of Silent Valley, Nelliampathy, Muthikkulam, Pothumala, Meenar (Nair and Balasubramanyan, 1985; Chandrashekara *et al.*, 1998; Chandrashekara and Jayaraman, 2002) identified *Cullenia exarillata* and *Palaquium ellipticum* as dominant trees. Among the sapling population, dominant species are *Cullenia exarillata*, *Palaquium ellipticum*, *Agrostistachys borneensis*, *Garcinia morella* *Diospyros bourdillonii* and *Myristica malabarica* are the dominant species.

Total number of individuals ($ha^{-1)}$ is 534 for mature trees and 859 for saplings. Number of tree species recorded per hectare is 25 which is lower than 33 (Attappadi), 37 (Silent valley) and 30 (Pothumala, Nelliampathy) Shruthakeerthiraja and Krishnakumar (2012) identified 1457 trees represented by 46 species under 44 genera in an enumeration of girth at breast height ≥ 10 cm Similarly, Strasberg (1995) identified (enumeration ≥30 cm gbh) 1270 trees in 4 species from the lowland rainforests of Oceanic island of La Reunion. A 1-h permanent plot established in the Réserve Naturelle Volontaire Trésor, Mts. de Kaw at highest rainfall area of French Guiana identified was 442 trees under 164 species (Steege *et al.*, 2003).

Table 3.7. Density of (individuals ha^{-1}) and importance value index (IVI) of matur trees (gbh ≥ 30.1 cm) and saplings (gbh 10.1 cm to 30.0 cm) in the permaner plots established at Silent valley.

Species	Mature trees		Saplings	
	Density	IVI	Density	IVI
Aglaia elaeagnoidea	3	2.21	1	0.28
Agrostistachys borneensis	69	26.07	97	36.09
Artocarpus heterophyllus	1	0.64	--	--
Artocarpus hirsutus	2	0.75	--	--
Calophyllum polyanthum	9	4.43	--	--
Canarium strictum	1	0.56	--	--
Cullenia exarillata	149	112.72	155	54.81
Dimocarpus longan	8	3.29	18	6.91

Diospyros bourdillonii	15	6.01	81	30.57
Dysoxylum malabaricum	9	4.21	12	3.98
Elaeocarpus tuberculatus	10	6.63	6	2.09
Garcinia morella	21	8.21	84	29.66
Hopea racophloea	2	0.97	4	1.57
Hydnocarpus alpina	28	12.15	27	9.70
Knema attenuata	18	8.03	24	8.44
Litsea floribunda	2	0.79	--	--
Mallotus philippensis	--	--	2	0.68
Mangifera indica	1	0.37	2	0.68
Meiogyne pannosa	4	1.51	44	15.44
Myristica malabarica	55	26.17	60	21.16
Palaquium ellipticum	103	48.08	110	38.56
Pavetta hispidula	2	0.75	9	2.87
Persea macrantha	30	19.86	9	3.33
Psychotria nigra	4	1.55	30	11.04
Syzygium hemisphericum	2	0.82	13	4.37
Syzygium laetum	8	3.12	49	17.66

Figure 3.3. Girth class distribution of individuals in the permanent plot established at Silent valley, Kerala.

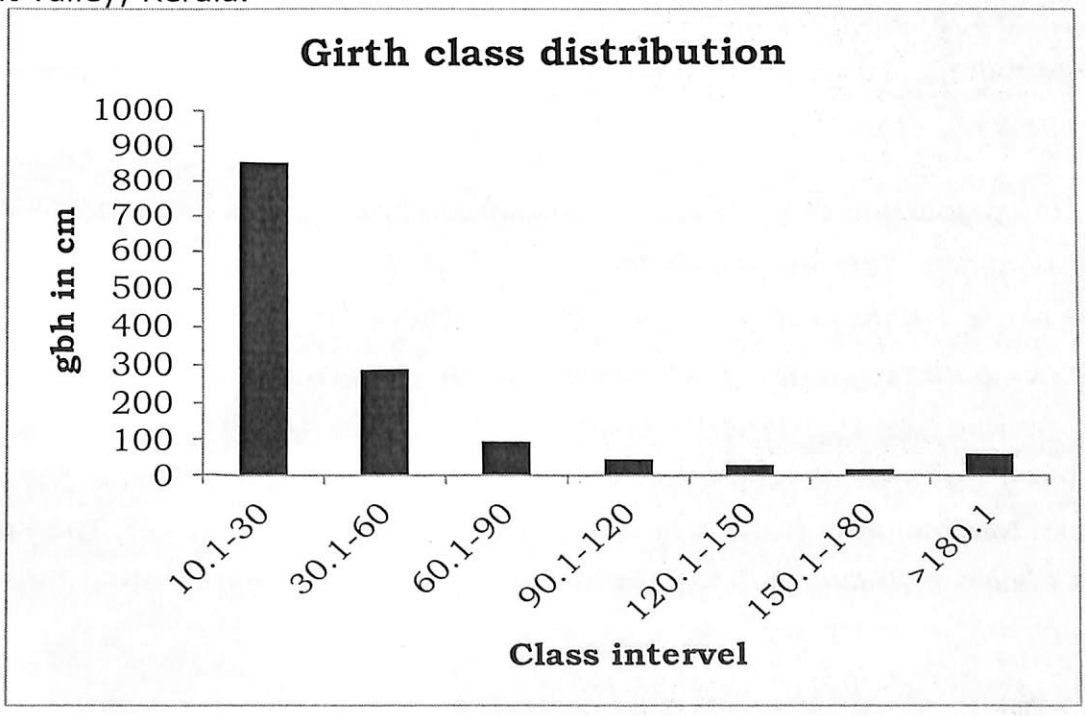


Table 3.8. Basic statistics of mature trees (gbh> 30.1 cm), saplings (gbh 10.1 cm to 30.0 cm) populations in the permanent plots at Silent Valley, Kerala.

Titles	Phases	
	Mature trees	**Saplings**
Families represented	18	16
Species represented	25	21
Total number of individuals (ha^{-1})	534	859
Total number of basal area (m^2 ha^{-1})	58.456	2.651
Species diversity index (H)	2.346	2.527
Species dominance value (C)	0.141	0.099

Tree species diversity was high for sapling phase compared to mature trees (Table 3.8). When compared to the species diversity recorded for mature trees (gbh more than 30.1 cm) in tropical rainforest of Barro Colorado Island (4.8; Knight, 1975) and in Kakachi. Kalakkad, India (4.87: Ganesh et al., 1996), in Silent valley, Kerala (4.89; Singh et al., 1981) and Pothumala, Kerala, (4.0; Chandrashekara and Ramakrishnan, 1994) the same recorded for the permanent plot established at Silent Valley is much lower (2.34). However when compared to the evergreen patches of Belthangady in Dakshina Kannada it is similar where the individuals girth at breast height ≥ 10 cm was enumerated (Shruthakeerthiraja and Krishnakumar, 2012).

Analysis of comparison of girth class distribution of all species in the plot indicated that the dominant species like *Cullenia exarillata*, *Palaquium ellipticum*, *Myristica malabarica* and *Persea macrantha* are represented in all girth classes (Table 3.9), however comparatively low representation occur in between class interval of 90 - 180 cm. Swaine and Hall (1988) reported that species capable of growing as top canopy trees are also disproportionately represented at Kade, Ghana and also in Pothumala, Nelliampathy (Chandrashekara and Ramakrishnan, 1992). The keystone species *Cullenia exarillata* is fairly represented individuals representing higher size class.

Table 3.9. Girth class distribution of trees in the permanent plot established at Silent valley

Species	Girth Classes						
	A	B	C	D	E	F	G
Aglaia elaeagnoidea	1		1			1	1
Agrostistachys borneensis	103	58	4	1			
Artocarpus heterophyllus					1		
Artocarpus hirsutus		2					
Calophyllum polyanthum		2	3	2	2		
Canarium strictum					1		
Cullenia exarillata	157	58	19	10	15	6	39
Dimocarpus longan	18	5	3				
Diospyros bourdillonii	81	11	3	1			
Dysoxylum malabaricum	12	6	1		1		1
Elaeocarpus tuberculatus	6	3	1	2			4
Garcinia morella	85	16	3	1			
Hopea racophloea	4		1	1			
Hydnocarpus alpina	27	21	4	1			2
Knema attenuata	25	10	6				1
Litsea floribunda		2					
Mallotus philippensis	2						
Mangifera indica	2	1					
Meiogyne pannosa	45	3					
Myristica malabarica	60	25	10	10	5	3	2
Palaquium ellipticum	117	48	24	12	3	4	5
Pavetta hispidula	9	2					
Persea macrantha	10	10	4	4	2	3	6
Psychotria nigra	32	1	1				
Syzygium hemisphericum	13	1	1				
Syzygium laetum	50	5	2				

*Girth classes: A- Saplings (gbh 10.0 cm to 30.0 cm), B to G - mature trees , 30.1cm - 60.0 cm, 60.1 cm - 90.0 cm , 90.1 cm - 120.0 cm. 120.1 cm - 150.0 cm, 150.1 cm - 180.0 cm, and >180.1 cm.

The distribution pattern of mature trees, saplings and seedlings in quadrats laid out in the permanent plot is represented in Appendices 1.5 & 1.6. These Tables will help in recensuses and also to understand the dynamics of trees.

3.1.4. **Vazhachal**

In the evergreen forest plot of Vazhachal, mature tree population is dominated by *Knema attenuata. Polyalthia coffeoides* and *Hydnocarpus pentandra* with 48% contribution to the total number of trees censused in the plot (Table 3.10). *Aporosa acuminata* is the dominant among sapling population followed by *Polyalthia coffeoides*. Out of 32 tree species recorded 24 species represented both two phases i.e. saplings and mature phases. The stem density recorded for mature trees and saplings seedlings are 329 and 550 respectively (Table 3.11) and it was 496, 900 (Chandrashekara and Ramakrishnan, 1994) and 542, 972 (Chandrashekara *et al.*, 1998) respectively in the case of permanent plot at Pothumala. Rasingam & Parthasarathy (2009) recorded 410 trees from the disturbed 1 ha evergreen plots of Little Andaman Islands where it was 488 in the case of undisturbed evergreen patch. Shruthakeerthiraja and Krishnakumar (2012) studied the phyto-sociology of one hectare plot in Belthangady, Dakshina Kannada (10 m X 10 m; all the trees, shrubs, lianas above 10 cm GBH, i.e, at 1.33 m (GBH – Girth at breast height) was marked) identified a total of 1,457 individuals with an average of 31.67 ± 77.26 (Median = 3) belonging to 46 tree species of 44 genera and 31 families. Similarly in the present study, the value is low when compared to the plots at Silent valley and Muthikkulam and comparatively the evergreen patches at vazhachal is highly disturbed when compared to other two locations.

Woody species richness and density decreased with increasing girth class exhibiting a reverse J-shaped stand structure. Majority of stems are found in the range of 10-30 cm girth class and generally the size-class distribution of individuals has been used to understand regeneration, disturbances and future stability of tree species in forest communities (Pandey, 2006). In the present study, reverse J-shaped population structure of trees was exhibited (Figure 3.4) as reported in many other forest stands in the Western Ghats like Kakachi, Uppangala, Mylodai-Courtallum reserve forest and high elevation forest of Kalakad (Parthasarathy, 2001), tropical wet evergreen forest of Namdapha national park, Arunachal Pradesh (Nath *et al.* 2005) and Little Andaman forest (Rasingam & Parthasarathy 2009). The reverse J-

shaped structure for girth frequency indicates good regeneration of the constituent species and it is dependent on the internal forest process and exogenic disturbance (Barker & Kinkpatrick, 1994). Table 3.12 shows girth class distribution of trees in the permanent plot established at Vazhachal.

All trees recorded in the quadrats studied are listed in Appendices 1.7 & 1.8 with quadrat number and number of individuals in a given quadrat to assist in locating each of them during recensus. The quadrat number and tag number of representative individuals of each species will be helpful for identification in the field.

Table 3.10. Density (individuals ha^{-1}) and importance value index (IVI) of mature trees (gbh ≥ 30.1 cm) and saplings (gbh 10.1 cm to 30.0 cm) in the permanent plots established at Vazhachal.

Species	Mature trees		Saplings	
	Density	IVI	Density	IVI
Aporosa acuminata	10	6.95	249	128.96
Artocarpus heterophyllus	1	1.33	--	--
Artocarpus hirsutus	7	11.87	1	0.61
Baccaurea courtallensis	5	3.13	5	3.31
Calophyllum polyanthum	1	1.14	--	--
Canarium strictum	1	0.67	--	--
Cinnamomum malabatrum	2	1.25	5	3.78
Dimocarpus longan	12	15.87	14	8.65
Diospyros buxifolia	--	--	11	6.97
Dysoxylum malabaricum	1	0.62	5	3.03
Garcinia morella	--	--	2	1.47
Holigarna arnottiana	12	12.37	2	1.15
Holigarna grahamii	3	3.21	--	--
Hopea parviflora	1	0.63	1	0.74
Hydnocarpus pentandra	26	22.45	46	27.75
Ixora brachiata	6	3.91	--	--
Knema attenuata	124	100.79	11	5.83
Mallotus philippensis	10	6.62	15	10.56

Mangifera indica	1	0.71	1	0.56
Melicope lunu-ankenda	6	5.59	28	16.69
Memecylon talbotianum	4	2.54	8	5.69
Myristica malabarica	24	20.59	2	1.44
Nothopegia travancorica	--	--	9	4.76
Otonephelium stipulaceum	2	1.38	--	--
Polyalthia coffeoides	34	22.32	119	60.31
Pterospermum reticulatum	2	2.11	--	--
Tabernaemontana alternifolia	--	--	1	0.51
UNV 1	7	13.75	3	2.24
UNV 2	5	5.05	3	2.15
UNV 3	9	8.38	2	1.52
UNV 4	5	5.87	2	1.23
UNV 5	12	18.79	--	--

Figure 3.4. Girth class distribution of individuals in the permanent plot established at Vazhachal, Kerala

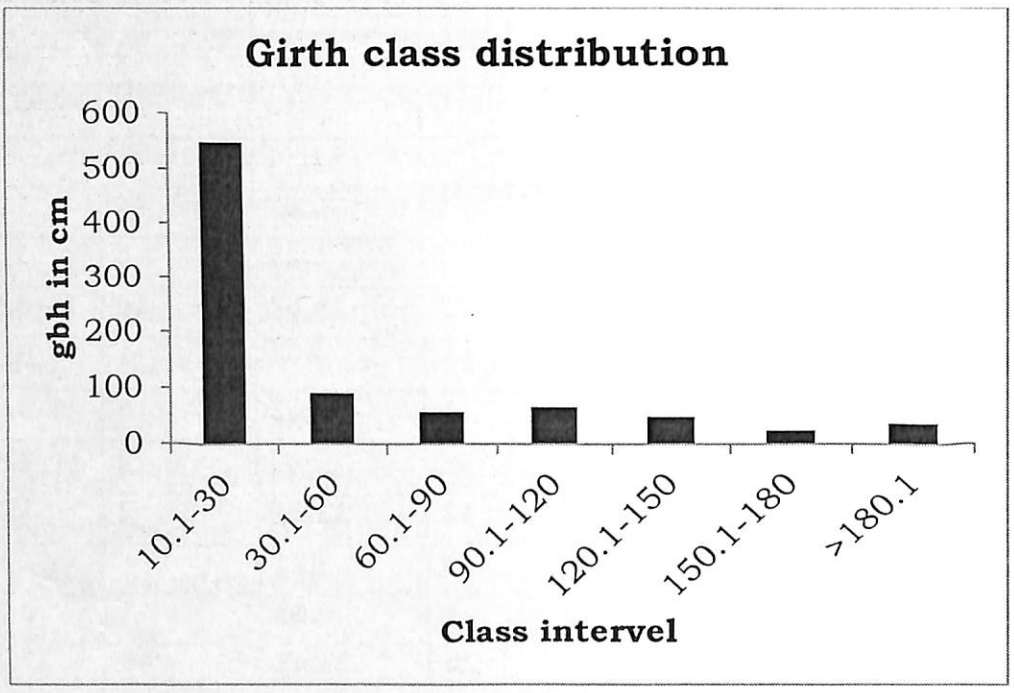


Table 3.11. Basic statistics of mature trees (gbh> 30.1 cm), saplings (gbh 10.1 cm to 30.0 cm) populations in the permanent plots at Vazhachal Kerala.

Titles	Phases	
	Mature trees	Saplings
Families represented	16	15
Species represented	28	24
Total number of individuals ($ha^{-1)}$	329	550
Total number of basal area (m^2 $ha^{-1)}$	81.908	1.091
Species diversity index (H)	2.422	1.869
Species dominance value (C)	0.171	0.268

Table 3.12. Girth class distribution of trees in the permanent plot established at Vazhachal

Species	Girth Classes						
	A	B	C	D	E	F	G
Aporosa acuminata	252	6	-	-	-	-	1
Artocarpus heterophyllus	-	-	-	-	-	-	1
Artocarpus hirsutus	1	-	1		1	-	5
Baccaurea courtallensis	7	3	-	-	-	-	-
Calophyllum polyanthum	-	-	-	-	-	-	1
Canarium strictum	-	-	1	-	-	-	-
Cinnamomum malabatrum	5	2	-	-	-	-	-
Dimocarpus longan	14	4	-	-	2	3	3
Diospyros buxifolia	11	-	-	-	-	-	-
Dysoxylum malabaricum	5	1	-	-	-	1	-
Garcinia morella	2	-	-	-	-	-	-
Holigarna arnottiana	2	-	2	2	2	2	4
Holigarna grahamii	-	1	-	-	1	-	1
Hopea parviflora	1	1	-	-	-	-	-
Hydnocarpus pentandra	46	8	4	5	2	5	2
Ixora brachiata	-	5	1	-	-	-	-
Knema attenuata	11	5	28	52	27	12	-
Mallotus philippensis	15	7	2	1	-	-	-
Mangifera indica	1		1	-	-	-	-
Melicope lunu-ankenda	28	2	1	1	1	-	1
Memecylon talbotianum	8	4	-	-	-	-	-

Myristica malabarica	1	7	4	2	7	-	4
Nothopegia travancorica	9	-	-	-	-	-	-
Otonephelium stipulaceum	-	1	-	1	-	-	-
Polyalthia coffeoides	119	25	7	-	2	-	-
Pterospermum reticulatum	-	-	1	-	-	-	1
Tabernaemontana alternifolia	1	-		-	-	-	-
UNV 1	4	3	1	-	-	1	2
UNV 2	3	3	-	1	-	-	1
UNV 3	2	1	3		2	1	2
UNV 4	2	2	-	1	-	-	2
UNV 5	-	-	1	1	3	-	7

*Girth classes: A- Saplings (gbh 10.0 cm to 30.0 cm), B to G - mature trees , 30.1cm - 60.0 cm, 60.1 cm - 90.0 cm , 90.1 cm - 120.0 cm. 120.1 cm - 150.0 cm, 150.1 cm - 180.0 cm, and >180.1 cm.

3.1.5. Kallipara, Parambikulam WLS

In the moist deciduous forest plot at Kallipara in Parambikkulam WLS shows that mature tree population is dominated by *Terminalia paniculata, Lagerstroemia microcarpa, Dillenia pentagyna* with 61% contribution to the total number of trees censused (Table 3.13). *Cassia fistula, Catunaregam spinosa, Terminalia paniculata* and *Diospyros cordifolia* are dominant among sapling population. Out of 22 tree species recorded 13 represented both mature and sapling phases.

The phyto-sociological studies on moist deciduous forests done by Chandrashekara and Jayaraman (2002) shows that *Xylia xylocarpa, Lagerstroemia microcarpa, Terminalia paniculata* and *Tectona grandis* as the dominat species and out of 22 plots established from moist deciduous forests of Kerala, eight were characterised by having *Xylia xylocarpa* as the first dominant species in the tree phase. Here in the present study dominant species is *Terminalia paniculata* in the tree phase and *Cassia fistula* in the sapling phase. Pascal (1988) also concluded that the moist impoverished soil conditions favours *Xylia xylocarpa* to flourish to become one of the dominant species. Other dominant species recorded from moist deciduous forests are *Lagerstroemia microcarpa, Terminalia tomentosa, Tectona grandis, Terminalia paniculata,* and *Wrightia tinctoria*. The phytosociological studies done one ha permanent plot at Channakkad done by Chandrashekara *et al.*, (1998) identified 98 mature trees ha-1 which represented mainly by deciduous species, is poorer in terms of stem density when compared to the moist deciduous forest of

Devadana, Chikmagalore District in the Western Ghats region {(344 trees ha -1); (Swamy. 1988)}. In the present study it is 205 trees ha-1 for mature trees and 205 saplings ha-1 respectively (Table 3.14). For mature trees 21 species are represented under 12 families. Different numbers of individuals are well represented in girth class (Table 3.15) ranging from 10.1 - 30, 30.1 to 60 and so on. Trees with gbh >180.1 cm are more than those of gbh ranging from 90.1-180.0 cm (Figure 3.5). The species like *Terminalia paniculata*, *Lagerstroemia microcarpa* and *Dillenia pentagyna* are represented individuals representing all girth classes.

It is concluded that the poor representation of girth class members especially those falling under middle size class may be attributed to illicit felling by the forest dwellers and residents of nearby areas.

Table 3.13. Density (individuals ha^{-1}) and importance value index (IVI) of mature trees (gbh ≥ 30.1 cm) and saplings (gbh 10.1 cm to 30.0 cm) in the permanent plots established at Kallipara.

Species	Mature trees		Saplings	
	Density	IVI	Density	IVI
Alstonia scholaris	1	1.08	1	4.02
Cassia fistula	24	25.21	19	72.35
Catunaregam spinosa	4	4.11	17	63.93
Dalbergia latifolia	2	2.71	--	--
Dillenia pentagyna	27	41.24	1	3.37
Diospyros cordifolia	1	0.99	8	29.45
Grewia tiliifolia	16	33.62	2	6.42
Haldina cordifolia	5	5.81	--	--
Lagerstroemia microcarpa	31	52.32	1	3.21
Macaranga peltata	5	6.56	--	--
Mallotus philippensis	--	--	1	3.37
Olea dioica	1	1.66	--	--
Tabernaemontana alternifolia	9	8.31	5	20.03
Tectona grandis	3	9.71	--	--
Terminalia bellirica	2	2.14	--	--
Terminalia paniculata	63	90.75	15	61.28

UNK	1	1.05	1	3.28
UNK1	1	1.01	5	16.86
UNK2	2	2.01	--	--
UNK5	1	1.01	--	--
Wrightia tinctoria	6	6.48	3	12.38
Ziziphus xylopyrus	2	2.18	--	--

Figure 3.5. Girth class distribution of individuals in the permanent plot established at Kallipara, Kerala

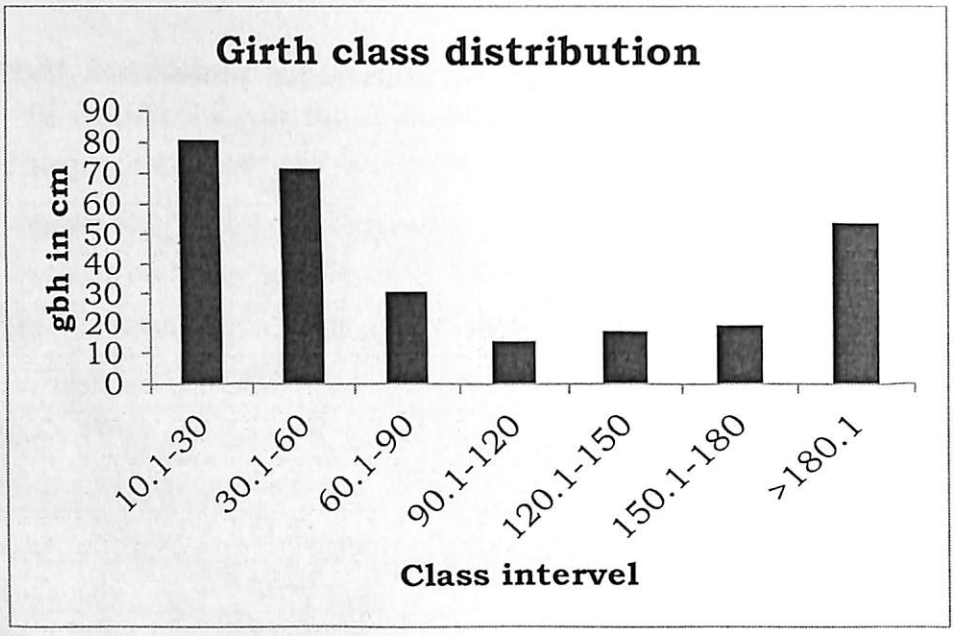


Table 3.14. Basic statistics of mature trees (gbh> 30.1 cm), saplings (gbh 10.1 cm to 30.0 cm) populations in the permanent plots at Kallipara, Kerala.

Titles	Phases	
	Mature trees	**Saplings**
Families represented	12	9
Species represented	21	13
Total number of individuals ($ha^{-1)}$	205	81
Total number of basal area (m^2 $ha^{-1)}$	43.798	0.35

Species diversity index (H)	2.231	2.058
Species dominance value (C)	0.154	0.151

Table 3.15. Girth class distribution of trees in the permanent plot established at Kallipara

Species	Girth Classes						
	A	B	C	D	E	F	G
Alstonia scholaris	1	-	1	-	-	-	-
Cassia fistula	20	19	3	-	-	-	1
Catunaregam spinosa	17	3	1	-	-	-	-
Dalbergia latifolia			1	-	-	-	1
Dillenia pentagyna	1	6	4	4	3	3	7
Diospyros cordifolia	9	-	-	-	-	-	-
Grewia tiliifolia	2	-	-	-	1	3	12
Haldina cordifolia	-	-	2	2	-	-	1
Lagerstroemia microcarpa	1	3	4	3	6	4	11
Macaranga peltata		-	1	1	1	1	1
Mallotus philippensis	1	-	-	-	-	-	-
Olea dioica		-	-	-	-	-	1
Tabernaemontana alternifolia	5	7	2	-	-	-	-
Tectona grandis	-	-	-	-	-	-	3
Terminalia bellirica	-	1	1	-	-	-	-
Terminalia paniculata	15	25	6	4	5	8	15
UNK	1		1	-	-	-	-
UNK1	5	1	-	-	-	-	-
UNK2	-	2	-	-	-	-	-
UNK5	-	1	-	-	-	-	-
Wrightia tinctoria	3	4	1	-	1	-	-
Ziziphus xylopyrus	-	-	2	-	-	-	-

*Girth classes: A- Saplings (gbh 10.0 cm to 30.0 cm), B to G - mature trees , 30.1cm - 60.0 cm, 60.1 cm - 90.0 cm , 90.1 cm - 120.0 cm. 120.1 cm - 150.0 cm, 150.1 cm - 180.0 cm, and >180.1 cm.

The occurrence of mature trees (gbh> 30.1 cm) and saplings (gbh 10.1-30.0 cm) of different species in quadrats of 1-ha permanent plot established at Kallipara is provided in the Appendices 1.9 and 1.10.

Muthikkulam

Analysis of 1 ha plot in Muthikkulam shows that *Cullenia exarillata, Palaquium ellipticum, Agrostistachys borneensis* and *Knema attenuata* are the dominant species in the mature tree phase which constituted about 51% of the mature tree population. In the case of sapling population *Palaquium ellipticum, Garcinia morella* and *Knema attenuata* are the dominant species (Table 3.16). Among these *Garcinia morella* is species of the understorey with small girth class. According to Pascal (1988), *Cullenia exarillata - Mesua ferrea- Palaquium ellipticum* type is the most important among the medium elevation forest types in the Western Ghats, both in area and quality and this type of forests are located in Silent Valley, Attappadi, and Nelliampathy (Pascal, 1988; Singh et al. 1981; Chandrashekara and Ramakrishnan, 1994). In Muthikkulam, some of the areas especially in Varadimala region this combination was observed. The number of tree species recorded per hectare in Muthikkulam is 39 where as in other studies it was 32, 37 and 30 respectively from Attappadi, Silent valley and Pothumala forest (Pascal, 1988; Singh et al. 1981; Chandrashekara and Ramakrishnan, 1994).

The stem density recorded for mature trees and saplings seedlings are 604 and 1301 respectively (Table 3.17) which is very high compared to 496, 900 (Chandrashekara and Ramakrishnan, 1994) and 542, 972 (Chandrashekara *et al.*, 1998) respectively in Pothumala, Nelliampathy. But it is low when compared to the stand density of other evergreen forest of the Western Ghats which are as follows; Idukki, 780 trees/ha; Nilambur, 908 tree/ha (Sanalkumar, 1997); Ranni, 892 trees/ ha; Parambikulam, 881trees/ha (Sankar and Sanalkumar, 1998); Silent Valley, 1082 trees/ha (Basha, 1987); Attappady, 1520 trees/ha (Pascal, 1988). Similarly very high tree density was recorded (1457 ha-1) from the low altitude forest of Dakshina Kannada (Shruthakeerthiraja and Krishnakumar, 2012) which also was much higher compared to 270 - 673 in low elevation Varagalaiar in Anamalais (Ayyappan & Parthasarathy 1999) and 395 – 734 as in tropical low altitude forests (Swaine *et al.* 1987).

Table 3.16. Density (individuals ha^{-1}) and importance value index (IVI) of mature trees (gbh ≥ 30.1 cm) and saplings (gbh 10.1 cm to 30.0 cm) in the permanent plots established at Muthikkulam.

Species	Mature trees		Saplings	
	Density	IVI	Density	IVI
Actinodaphne salicina	14	5.31	24	5.74
Aglaia lawii	26	9.47	49	11.31
Agrostistachys borneensis	83	30.36	47	10.67
Antidesma montanum	2	0.72	8	1.77
Aphanamixis polystachya	--	--	13	2.69
Artocarpus heterophyllus	--	--	1	0.24
Artocarpus hirsutus	--	--	1	0.21
Baccaurea courtallensis	--	--	6	1.31
Canarium strictum	1	0.36	5	1.15
Cinnamomum macrocarpum	2	0.74	1	0.31
Cinnamomum malabatrum	1	0.39		
Cullenia exarillata	34	52.42	55	12.79
Dimocarpus longan	1	0.36	5	1.35
Diospyros assimilis	26	10.05	47	11.24
Diospyros trichophylla	1	0.35	3	0.61
Drypetes venusta	2	1.06	1	0.21
Drypetes wightii	34	14.98	22	5.34
Flacourtia montana	--	--	1	0.24
Garcinia morella	43	16.14	147	33.11
Gomphandra tetrandra	1	0.46	62	13.15
Heritiera papilio	6	2.27	13	2.93
Holigarna arnottiana	5	2.41	6	1.36
Holigarna grahamii	3	1.71	6	1.25
Hydnocarpus pentandra	4	1.61	13	2.65
Ixora brachiata	--	--	5	1.06
Knema attenuata	60	27.49	91	21.85
Litsea floribunda	12	5.75	14	3.39

Macaranga peltata	9	3.75	2	0.55
Mangifera indica	2	0.72	--	--
Mastixia arborea	--	--	2	0.48
Meiogyne pannosa	--	--	5	1.11
Mesua ferrea	13	12.35	21	4.64
Myristica malabarica	40	16.62	74	18.79
Nothopegia racemosa	1	0.34	23	4.89
Oreocnide integrifolia	1	0.34	--	--
Palaquium ellipticum	87	43.39	282	64.73
Paracroton pendulus	14	5.34	17	4.38
Phoebe lanceolata	8	2.91	32	8.08
Poeciloneuron indicum	3	1.41	--	--
Polyalthia coffeoides	29	11.54	27	6.39
Psychotria nigra	--	--	1	0.19
Syzygium gardneri	5	3.71	8	2.11
Syzygium hemisphericum	1	0.39	1	0.21
Syzygium laetum	15	7.03	65	14.12
Syzygium mundagam	5	1.91	36	7.78
Syzygium munronii	4	1.46	31	6.81
Trichilia connaroides	--	--	4	1.13
UN S 1	1	0.41	1	0.25
UN S 2	--	--	1	0.18
UN S 3	--	--	1	0.32
UN S 4	--	--	1	0.18
UN S 5	--	--	1	0.18
UN S 6	--	--	1	0.28
Vepris bilocularis	--	--	1	0.21
Xanthophyllum arnottianum	5	1.84	17	3.91

Figure 3.6. Girth class distribution of individuals in the permanent plot established at Siruvani, Kerala

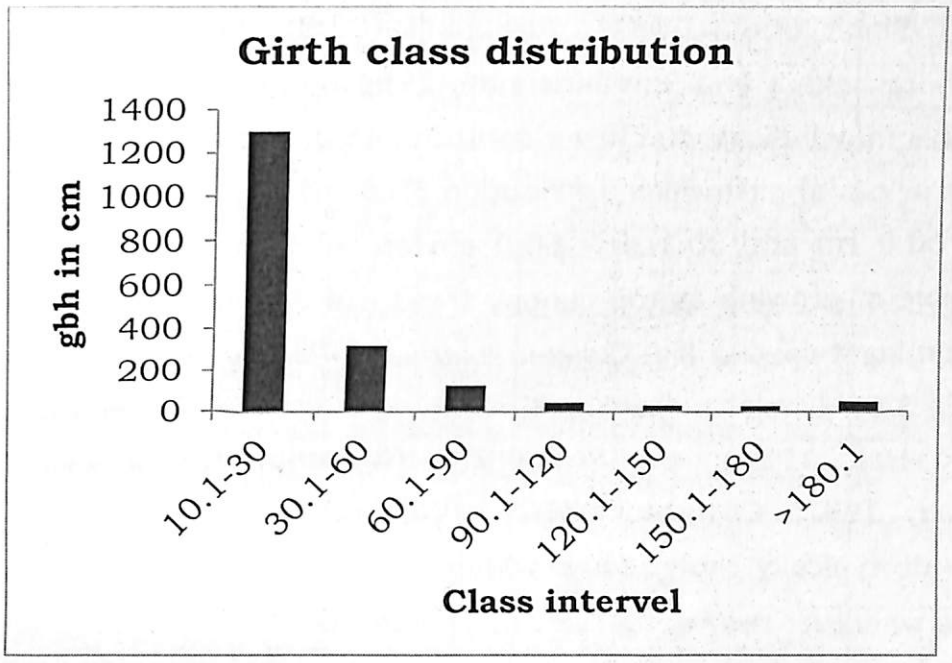


Table 3.17. Basic statistics of mature trees (gbh> 30.1 cm), saplings (gbh 10.1 cm to 30.0 cm) populations in the permanent plots at Muthikulam, Kerala.

Titles	Phases	
	Mature trees	Saplings
Families represented	17	21
Species represented	39	51
Total number of individuals (ha^{-1})	604	1301
Total number of basal area (m^2 ha^{-1})	63.844	3.252
Species diversity index (H)	2.931	3.01
Species dominance value (C)	0.073	0.082

Tree species diversity was high for sapling phase followed by mature trees (Table 3.12). The species diversity recorded for mature trees (gbh more than 30.1 cm) in the present study is 2.9 which is much lower when compared to Silent valley, (4.89; Singh et al., 1981), Pothumala, Nelliampathy (4.0; Chandrashekara and Ramakrishnan, 1994 and 3.9; Chandrashekara et al., 1998), Kakachi. Kalakkad (4.87; Ganesh et al., 1996) and tropical rainforest of Barro Colorado Island (4.8; Knight, 1975).

The value obtained for the concentration of dominance for mature tree layer (0.073) in the present study is much lower than those recorded for forests in Silent valley (0.06; Singh et.al., 1981), Attappadi (0.90; Pascal, 1988), Pothumala (0.086; Chandrashekara and Ramakrishnan, 1994 and 0.1069; Chandrashekara et al., 1998). This may indicate the lower contribution of dominant species to the total IVI values. Analysis of girth class distribution (Table 3.18) shows that saplings (gbh 10.1 cm to 30.0 cm and 30.1cm - 60.0 cm are maximum represented and tree species capable of growing as top canopy trees are disproportionately represented except for dominant species like *Cullenia exarillata, Palaquium ellipticum and Mesua ferrea* (Figure 3.6). Similar pattern was observed in other areas like at Kade, Ghana (Swaine and Hall, 1988), and Pothumala, Nelliampathy (Chandrashekara and Ramakrishnan, 1992; Chandrashekara et al., 1998) in such disproportionate presentation do typically show poorer regeneration except for dominant species on a wider scale wherever they occur needs to be studied.

Table 3.18. Girth class distribution of trees in the permanent plot established at Muthikkulam

Species	Girth Classes						
	A	B	C	D	E	F	G
Actinodaphne salicina	24	7	5	2	-	-	-
Aglaia lawii	49	19	7	-	-	-	-
Agrostistachys borneensis	47	59	23	-	1	-	-
Antidesma montanum	8	2	-	-	-	-	-
Aphanamixis polystachya	13	-	-	-	-	-	-
Artocarpus heterophyllus	1	-	-	-	-	-	-
Artocarpus hirsutus	1	-	-	-	-	-	-
Baccaurea courtallensis	6	-	-	-	-	-	-
Canarium strictum	5	1		-	-	-	-
Cinnamomum macrocarpum	1	1	1	-	-	-	-
Cinnamomum malabatrum	-	-	1	-	-	-	-
Cullenia exarillata	55	6	1	1	1	2	23
Dimocarpus longan	5	1	-	-	-	-	-
Diospyros assimilis	47	16	8	1	-	1	-
Diospyros trichophylla	3	1	-		-	-	-
Drypetes venusta	1	-	-	1	-	1	-
Drypetes wightii	22	14	9	5	3	1	2
Flacourtia montana	1	-	-	-	-	-	-
Garcinia morella	147	29	13	1	-	-	-

Gomphandra tetrandra	62	-	-	1	-	-	-
Heritiera papilio	13	5	-	1	-	-	-
Holigarna arnottiana	6	3	-	-	-	2	-
Holigarna grahamii	6	-	1	-	-	2	-
Hydnocarpus pentandra	13	3	-	-	1		-
Ixora brachiata	5	-	-	-	-	-	-
Knema attenuata	91	20	12	10	12	4	2
Litsea floribunda	14	5	2		2	1	2
Macaranga peltata	2	2	6		1		
Mangifera indica	-	2	-	-	-	-	-
Mastixia arborea	2	-	-	-	-	-	-
Meiogyne pannosa	5	-	-	-	-	-	-
Mesua ferrea	21	2	3	1	-	3	4
Myristica malabarica	74	23	8	5	-	3	1
Nothopegia racemosa	23	1	-	-	-	-	-
Oreocnide integrifolia	-	1	-	-	-	-	-
Palaquium ellipticum	282	47	10	5	4	7	14
Paracroton pendulus	17	10	1	2	1	-	-
Phoebe lanceolata	32	7	1	-	-	-	-
Poeciloneuron indicum	-	-	-	2	1	-	-
Polyalthia coffeoides	27	14	8	5	2	-	-
Psychotria nigra	1	-	-	-	-	-	-
Syzygium gardneri	8	3	-	-	-	-	2
Syzygium hemisphericum	1		1		-	-	
Syzygium laetum	65	8	4	2	-	-	1
Syzygium mundagam	36	3	1	1	-	-	-
Syzygium munronii	31	4	-	-	-	-	-
Trichilia connaroides	4	-	-	-	-	-	-
UN S 1	1	-	1	-	-	-	-
UN S 2	1	-	-	-	-	-	-
UN S 3	1	-	-	-	-	-	-
UN S 4	1	-	-	-	-	-	-
UN S 5	1	-	-	-	-	-	-
UN S 6	1	-	-	-	-	-	-
Vepris bilocularis	1	-	-	-	-	-	-
Xanthophyllum arnottianum	17	4	1	-	-	-	-

*Girth classes: A- Saplings (gbh 10.0 cm to 30.0 cm), B to G - mature trees , 30.1cm - 60.0 cm, 60.1 cm - 90.0 cm , 90.1 cm - 120.0 cm. 120.1 cm - 150.0 cm, 150.1 cm - 180.0 cm, and >180.1 cm.

The distribution of mature trees and saplings of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot at Muthikulam is shown in Appendices 1.11.and 1.12.

4. CONCLUSION

One hectare permanent plots were established in relatively undisturbed patches of evergreen, moist deciduous, dry deciduous and shola forests in Kerala part of the Western Ghats. These plots can be used as benchmark plots to track ecological processes, changes in forest habitat, biodiversity measurement and climate change effects. Long-term studies in permanent plots established in these forest types will be helpful to evaluate the changes in tree species diversity, composition and dynamics in relation to the degree and frequency of disturbance. Moreover the studies on quantification and variation in carbon pools and fluxes, plant functional traits, monitoring plant phenology, seed dispersal, arthropod assemblages etc., can also be undertaken. Finally this can be linked to long term national and international monitoring net-work systems.

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6. APPENDICES

Appendix 1.1. Occurrence of mature trees (gbh> 30.1 cm) of different species in quadrats (10m × 10m) laid out in the 1-ha permanent plot established at Vaguvarai, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Actinodaphne bourdillonii	29 (1)	32 (1)									
Aglaia apiocarpa	64 (1)										
Apollonias arnottii	12 (1)	17 (1)	24 (1)	25 (1)	30 (1)	52 (1)					
Aporosa fusiformis	4 (2)	7 (2)	8 (1)	9 (1)	10 (2)	14 (1)	15 (1)	17 (1)	23 (1)	24 (1)	26 (2)
	29 (1)	30 (1)	31 (1)	68 (1)	70 (1)	72 (1)	75 (1)	86 (1)	87 (1)	88 (1)	91 (1)
	93 (1)										
Beilschmiedia wightii	4 (1)	6 (2)	7 (2)	76 (1)	93 (1)	96 (1)					
Bhesa indica	29 (1)										
Canarium strictum	10 (3)										
Celtis tetrandra	36 (1)										
Chionanthus ramiflorus	14 (1)	15 (1)	16 (1)	28 (2)	29 (1)	31 (1)	33 (1)	36 (1)	43 (1)	44 (1)	45 (1)
	46 (2)	48 (1)	50 (2)	55 (1)							
Cinnamomum sulphuratum	10 (1)	35 (1)									
Cinnamomum wightii	4 (1)	8 (1)	14 (1)	24 (1)	25 (1)	27 (1)	28 (1)	30 (1)	32 (1)	33 (1)	35 (2)
	43 (1)	47 (2)	48 (1)	49 (1)	53 (1)	67 (1)	70 (1)	74 (1)	87 (1)	90 (1)	93 (1)
	94 (1)										
Elaeocarpus recurvatus	53 (1)	72 (1)	87 (1)	92 (1)	95 (1)						
Garcinia cowa	9 (1)	15 (1)	16 (1)	25 (1)	27 (2)	30 (1)	31 (1)	32 (1)	45 (2)	46 (1)	65 (2)
	68 (1)	69 (1)	71 (1)	73 (1)	78 (1)	87 (1)	89 (1)	92 (1)	96 (1)		
Glochidion neilgherrence	5 (1)	15 (1)	17 (2)	27 (1)	29 (1)	34 (2)	35 (3)	42 (1)	49 (1)	53 (2)	54 (2)
	55 (1)	56 (4)	68 (1)	70 (1)	71 (1)	73 (1)	88 (1)	90 (1)	95 (1)		
	5 (1)	6 (1)	7 (2)	25 (2)	26 (1)	28 (1)	30 (1)	32 (1)	34 (1)	35 (1)	43 (1)
Gomphandra coriacea	44 (1)	45 (1)	47 (1)	48 (1)	51 (2)	52 (1)	64 (2)	65 (3)	66 (1)	67 (1)	68 (1)
	70 (1)	71 (2)	72 (1)	74 (1)	75 (2)	86 (1)	87 (1)	88 (1)	89 (1)	90 (1)	91 (1)
	93 (1)	96 (1)									
Ilex gardneriana	31 (3)	42 (1)	45 (2)	46 (3)	47 (1)	51 (1)	52 (1)	57 (1)	65 (2)	66 (1)	67 (1)

	70 (1)	72 (1)	87 (1)	88 (1)	91 (1)						
Isonandra perottetiana	4 (1)	25 (1)	64 (1)	68 (1)	69 (1)	70 (1)	71 (1)	73 (1)	84 (1)	86 (1)	88 (1)
	90 (1)										
Litsea glabrata	4 (1)	8 (2)	10 (1)	51 (2)	67 (1)	71 (1)					
Microtropis ramiflora	4 (1)	7 (1)	8 (1)	10 (1)	13 (1)	14 (1)	28 (1)	30 (1)	32 (1)	33 (1)	35 (1)
	36 (2)	42 (1)	50 (1)	53 (1)	55 (1)	63 (1)					
Neolitsea scrobiculatus	7 (2)	4 (1)	10 (1)	15 (4)	23 (1)	26 (1)	28 (1)	30 (1)	32 (1)	35 (1)	36 (1)
	42 (1)	44 (1)	47 (1)	48 (1)	49 (1)	50 (1)	51 (1)	54 (1)	57 (1)	66 (1)	
Nothapodytes nimmoniana	8 (1)	33 (1)	36 (1)								
Persea macrantha	57 (1)										
Psychotria truncata	5 (1)	72 (1)	88 (1)								
Saprosma foetens	6 (1)	45 (1)	63 (1)	64 (1)	69 (1)	70 (2)	71 (1)	87 (1)	88 (1)	94 (1)	
Schefflera capitata	3 (1)	71 (1)	75 (1)	88 (1)	94 (1)						
Scolopia crenata	4 (1)	36 (1)	50 (1)	56 (1)	69 (1)	70 (1)	74 (1)	85 (1)	89 (1)		
Symplocos macrophylla	4 (1)	9 (1)	12 (1)	13 (1)	14 (1)	15 (1)	17 (1)	24 (2)	25 (2)	26 (2)	27 (1)
	29 (3)	30 (4)	31 (2)	33 (2)	34 (1)	36 (1)	42 (2)	45 (3)	47 (1)	49 (1)	52 (3)
	68 (1)	69 (1)	70 (1)	72 (1)	85 (1)	87 (1)	89 (1)				
Syzygium densiflorum	3 (1)	5 (1)	10 (1)	11 (2)	12 (1)	13 (1)	14 (1)	16 (1)	26 (1)	31 (1)	32 (2)
	35 (1)	36 (1)	46 (1)	47 (1)	49 (1)	52 (1)	53 (2)	65 (1)	70 (1)	75 (1)	86 (1)
	88 (1)	90 (1)	92 (1)								
Syzygium lanceolatum	3 (1)	6 (1)	26 (1)								
Unidentified -1	5 (1)	24 (1)	43 (2)	68 (1)	69 (1)	72 (1)	86 (1)	90 (1)	93 (1)		
Unidentified -2	54 (1)										
Unidentified -3	64 (1)	70 (1)	71 (1)	89 (1)	94 (1)						
Unidentified -4	26 (1)	44 (1)	69 (1)	70 (1)	73 (1)	91 (1)					
Xanthophyllum arnottianum	31 (1)	72 (1)	78 (1)	87 (1)	91 (1)						

Appendix 1.2. Occurrence of saplings (gbh 10.1-30.0 cm) of different species in quadrats (10m × 10m) laid out in the 1-ha permanent plot established at Vaguvarai, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Aglaia apiocarpa	15 (1)	36 (1)									
Apollonias arnottii	11 (1)	12 (1)	13 (1)	24 (1)	25 (1)	26 (3)	29 (1)	30 (1)	34 (3)	36 (1)	50 (3)
	68 (1)	71 (1)	74 (1)	85 (1)	89 (1)	91 (1)					
Aporosa fusiformis	5 (1)	14 (1)	86 (1)								
Beilschmiedia wightii	4 (3)	6 (1)	9 (2)	29 (1)	67 (1)	68 (2)	69 (1)	87 (1)			
Bhesa indica	27 (1)										
Chionanthus ramiflorus	11 (1)	12 (1)	13 (3)	15 (1)	23 (1)	24 (2)	25 (1)	27 (2)	29 (1)	35 (3)	36 (3)
	43 (1)	46 (1)	47 (1)	48 (1)	50 (3)	54 (2)	55 (1)	68 (1)			
Cinnamomum wightii	12 (1)	15 (1)	42 (1)								
Garcinia cowa	4 (2)	28 (1)	32 (1)	67 (1)							
Glochidion neilgherrence	4 (1)	7 (1)	15 (1)	17 (1)	23 (1)	24 (1)	28 (1)	30 (1)	33 (1)	34 (1)	35 (2)
	36 (2)	42 (1)	43 (2)	44 (1)	45 (1)	47 (1)	49 (1)	50 (2)	52 (2)	54 (1)	55 (1)
	56 (2)	57 (2)	67 (1)	76 (1)	85 (1)						
Gomphandra coriacea	6 (1)	9 (2)	16 (1)	24 (1)	25 (1)	33 (1)	34 (1)	35 (1)	44 (1)	57 (1)	72 (1)
	73 (1)	76 (1)	86 (2)	88 (1)							
Ilex gardneriana	30 (3)	33 (1)	36 (2)	42 (1)	49 (1)	53 (2)	55 (1)	56 (1)	69 (2)	73 (1)	86 (1)
	96 (1)										
Isonandra perottetiana	9 (1)	12 (1)	15 (1)	23 (1)	27 (1)	93 (1)					
Litsea glabrata	8 (1)	9 (2)	10 (2)	25 (1)	34 (1)	46 (1)	53 (1)	57 (1)	68 (1)	70 (1)	72 (1)
	74 (1)	86 (1)	88 (1)	90 (1)	94 (1)						
Litsea oleoides	5 (2)	8 (2)	9 (1)	12 (1)	30 (1)	56 (1)	67 (1)	68 (1)			
Microtropis ramiflora	5 (1)	7 (1)	8 (3)	13 (1)	33 (1)	34 (1)	42 (1)	44 (1)	45 (1)	52 (1)	69 (1)
	71 (1)	72 (1)	85 (1)	87 (1)	89 (1)	93 (1)					
Neolitsea scrobiculatus	4 (1)	5 (1)	6 (2)	9 (2)	12 (2)	13 (1)	15 (2)	24 (1)	31 (1)	35 (1)	36 (1)
	47 (1)	51 (1)	53 (1)	57 (1)	63 (1)	64 (1)	67 (1)	69 (1)			
Nothapodytes nimmoniana	34 (1)	35 (1)	49 (1)	71 (1)	88 (1)	92 (1)					
Persea macrantha	54	68	70	71	73	84	87	88	91	97	

	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
Psychotria truncata	7 (1)	26 (1)	85 (1)	87 (1)							
Rhododendron arboreum	84 (1)	97 (1)									
Saprosma foetens	32 (1)	46 (1)	53 (1)								
Scolopia crenata	36 (1)	93 (1)	95 (1)								
Symplocos macrophylla	3 (1)	7 (2)	10 (2)	12 (2)	13 (1)	14 (3)	15 (4)	17 (2)	24 (1)	27 (2)	28 (1)
	29 (3)	30 (1)	42 (1)	44 (1)	51 (1)	65 (1)	93 (1)				
Syzygium densiflorum	30 (1)										
Syzygium lanceolatum	6 (1)										
Unidentified -1	8 (1)	9 (1)	44 (1)	56 (1)							
Unidentified -2 Unidentified -3	3 (1)	17 (3)	24 (1)	25 (1)	28 (2)	33 (2)	34 (1)	35 (2)	43 (1)	47 (1)	49 (2)
	53 (2)	54 (1)	55 (2)								
Unidentified -4	17 (1)	28 (1)	56 (1)								
Unidentified -1	26 (1)	77 (1)									
Xanthophyllum arnottianum	13 (1)										

Appendix 1.3. Occurrence of mature trees (gbh> 30.1 cm) of different species in quadrats (10m × 10m) laid out in the 1-ha permanent plot established at Champakad, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Albizia amara	78 (1)										
Alphonsea sclerocarpa	11 (3)	33 (1)	35 (1)	53 (1)	54 (1)	75 (1)	76 (1)	85 (1)	86 (1)	90 (1)	91 (1)
	96 (2)	97 (1)									
Anogeissus latifolia	12 (1)	17 (1)	21 (1)	22 (1)	37 (1)	40 (1)	41 (1)	43 (1)	65 (1)		
Atlantia monophylla	1 (1)	6 (1)	8 (2)	9 (1)	10 (1)	11 (3)	13 (1)	15 (1)	19 (1)	24 (2)	26 (1)
	27 (1)	32 (1)	44 (3)	45 (1)	48 (1)	51 (1)	53 (1)	56 (1)	64 (2)	68 (2)	69 (2)
	71 (1)	72 (1)	74 (1)	80 (1)	87 (1)	88 (1)	100 (1)				
Azadirachta indica	12 (2)										
Bauhinia malabarica	12 (1)	23 (1)	30 (1)	41 (1)	44 (1)	48 (1)	75 (2)	92 (1)			
Canthium coromandelicum	24 (1)	25 (1)	40 (1)	96 (1)							
Carissa spinarum	14 (1)										
Catunaregam spinosa	22	32	34	41	42	43	66	68			

	(1)	(1)	(1)	(1)	(3)	(1)	(1)	(2)			
Celtis timorensis	28 (1)	31 (3)	32 (1)	72 (1)	76 (1)	86 (1)	87 (1)	89 (1)			
Chloroxylon swietenia	2 (1)	21 (1)	44 (1)	57 (1)	60 (1)	66 (1)	73 (1)	76 (2)	77 (1)		
Commiphora berryi	1 (1)	3 (1)	17 (1)	18 (1)	20 (1)	41 (1)	59 (1)	79 (1)			
Commiphora caudata	14 (1)	16 (1)	23 (1)	25 (1)	41 (1)	42 (1)	44 (2)	58 (1)	63 (1)	64 (1)	80 (1)
	84 (2)	98 (2)									
Crataeva adansonii	10 (2)	11 (1)									
Dalbergia latifolia	7 (1)	12 (1)	15 (1)	27 (1)							
Dalbergia lanceolaria	70 (1)										
Diospyros cordifolia	63 (1)	91 (1)	98 (1)								
Diospyros ebenum	11 (1)	13 (1)	29 (1)	39 (1)	47 (2)	48 (1)					
Diospyros ferrea	20 (1)	28 (1)									
Diospyros latifolia	67 (1)	68 (1)	75 (2)	76 (1)							
Dolichandrone arcuata	1 (1)	56 (1)	60 (2)	61 (1)							
Erythroxylum monogynum	8 (1)	25 (1)	33 (1)	38 (1)	46 (1)	48 (1)	49 (1)	53 (3)	75 (1)	85 (2)	87 (2)
	88 (2)	89 (1)	95 (1)	96 (1)	97 (1)						
Ficus mollis	82 (1)										
Flacourtia montana	34 (1)										
Gardenia gummifera	77 (1)	81 (1)									
Gardenia spp	2 (1)										
Glycosmis pentaphylla	53 (1)	67 (1)	69 (1)								
Gmelina asiatica	5 (1)										
Grewia barberi	77 (1)										
Grewia villosa	7 (1)	17 (1)	18 (1)	19 (1)	26 (1)	27 (1)	43 (1)	62 (1)	65 (1)	78 (1)	80 (1)
	81 (1)	83 (1)									
Ixora brachiata	83 (1)	84 (1)									
Lannea coromandelica	19 (1)										
Pavetta indica	1 (1)	2 (2)	4 (2)	7 (2)	8 (1)	21 (1)	34 (1)	38 (1)	45 (1)	95 (1)	96 (1)
Pleiospermium alatum	29 (1)	51 (1)	73 (1)	87 (1)	88 (1)	95 (1)					
Sapindus emarginatus	11 (1)	12 (1)	28 (1)	33 (1)	46 (1)	49 (1)	73 (3)	84 (1)	92 (1)	93 (1)	
Schleichera oleosa	28 (2)	50 (2)	51 (1)								

Sterculia urens	5 (1)	8 (1)	16 (1)	35 (1)	36 (1)	55 (1)					
Strychnos nux-vomica	30 (1)	31 (1)									
Strychnos potatorum	2 (1)	20 (1)	27 (1)	28 (1)	31 (1)	35 (1)	36 (1)	38 (2)	50 (2)	53 (2)	54 (1)
	72 (1)	73 (2)	76 (1)	78 (1)	81 (1)						
Tamarindus indica	90 (1)										
Ziziphus oenoplia	71 (1)										

Appendix 1.4. Occurrence of saplings (gbh 10.1-30.0 cm) of different species in quadrats (10m × 10m) laid out in the 1-ha permanent plot established at Champakad, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Alphonsea sclerocarpa	7 (1)	11 (1)	13 (1)	36 (1)	52 (1)	76 (2)	86 (1)	87 (1)			
Anogeissus latifolia	8 (1)	27 (1)	36 (1)	38 (2)	42 (1)	55 (1)	62 (1)	99 (1)			
Atlantia monophylla	1 (1)	2 (1)	3 (2)	7 (1)	8 (3)	9 (2)	10 (4)	11 (2)	12 (3)	13 (3)	14 (2)
	18 (1)	20 (2)	22 (3)	23 (6)	24 (1)	26 (1)	27 (1)	28 (5)	31 (2)	32 (7)	35 (1)
	36 (1)	37 (3)	38 (4)	39 (1)	44 (2)	46 (1)	48 (2)	49 (6)	50 (1)	51 (1)	52 (9)
	53 (5)	54 (1)	58 (1)	61 (2)	62 (1)	63 (1)	68 (4)	69 (3)	70 (1)	72 (2)	73 (3)
Atlantia monophylla	74 (4)	75 (5)	76 (1)	77 (1)	81 (1)	82 (1)	83 (1)	84 (1)	87 (3)	88 (3)	96 (1)
	98 (1)	99 (1)	100 (1)								
Bauhinia malabarica	12 (2)	21 (1)	75 (1)	94 (1)							
Canthium coromandelicum	39 (1)	40 (2)									
Carissa spinarum	13 (1)	66 (2)	67 (2)	68 (2)	76 (1)	88 (2)					
Catunaregam spinosa	23 (1)	28 (1)	29 (1)	33 (1)	34 (1)	36 (2)	38 (1)	40 (1)	41 (2)	43 (1)	53 (1)
	54 (1)	55 (1)	57 (1)	60 (3)	61 (1)	63 (1)	69 (2)	70 (1)	71 (1)	82 (1)	
Celtis timorensis	32 (2)	33 (1)	43 (1)	47 (2)	52 (1)	69 (2)	83 (1)	85 (1)			
Chloroxylon swietenia	1 (2)	35 (2)	37 (1)	38 (1)	40 (1)	41 (1)	44 (1)	57 (1)	59 (1)	61 (1)	80 (1)
	82 (1)										
Combretum albidum	30 (1)										
Commiphora caudata	44 (1)	60 (1)	62 (1)	63 (1)	70 (1)	74 (2)	80 (1)	85 (1)	86 (1)	87 (1)	89 (1)
	94 (1)	97 (1)									

Crataeva adansonii	7 (2)	10 (2)	11 (3)	12 (2)							
Dalbergia latifolia	27 (1)										
Diospyros cordifolia	74 (2)	93 (1)									
Diospyros ebenum	13 (1)	35 (1)	36 (3)	43 (1)	47 (1)						
Diospyros latifolia	51 (1)	66 (1)	67 (1)	74 (1)	75 (1)	76 (2)	90 (1)	93 (1)	97 (2)		
Dolichandrone arcuata	57 (1)										
Erythroxylum monogynum	13 (2)	14 (1)	20 (1)	27 (2)	35 (1)	36 (1)	38 (1)	39 (2)	53 (2)	56 (1)	60 (1)
	66 (1)	67 (1)	75 (1)	89 (2)	92 (1)	95 (1)	100 (1)				
Flacourtia montana	32 (1)	33 (1)									
Gardenia gummifera	97 (1)										
Glycosmis pentaphylla	27 (2)	28 (2)	33 (1)	34 (2)	48 (1)	50 (1)	52 (1)	53 (1)	68 (1)	69 (4)	70 (3)
	72 (1)	73 (2)	74 (1)	75 (2)	76 (3)	87 (4)	88 (2)	94 (3)	95 (2)	96 (1)	
Gmelina asiatica	3 (1)	8 (1)									
Grewia villosa	6 (1)	7 (1)	20 (1)	23 (1)	24 (1)	27 (1)	35 (1)	55 (1)	58 (1)	65 (1)	66 (1)
	74 (1)	75 (1)	78 (1)	81 (1)	84 (1)	99 (2)	100 (1)				
Pavetta indica	8 (1)	32 (1)	35 (1)	44 (1)	50 (1)	51 (1)	95 (2)				
Pleiospermium alatum	49 (3)	52 (2)	73 (1)	74 (5)	87 (2)						
Sapindus emarginatus	11 (2)	28 (3)	32 (3)	48 (1)	49 (1)	50 (1)	51 (3)	52 (2)	72 (1)	74 (1)	89 (1)
Schleichera oleosa	52 (1)										
Sterculia urens	3 (1)	15 (1)	16 (1)	35 (1)							
Strychnos nux-vomica	30 (1)										
Strychnos potatorum	10 (3)	11 (2)	13 (1)	27 (2)	28 (1)	31 (3)	35 (1)	36 (1)	37 (1)	44 (1)	49 (1)
	52 (1)	73 (1)	74 (1)								

Appendix 1.5. Occurrence of mature trees (gbh> 30.1 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Silent valley, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Aglaia elaeagnoidea	22 (1)	23 (1)	25 (1)								
Agrostistachys borneensis	1 (1)	2 (1)	3 (1)	4 (2)	5 (1)	6 (1)	7 (4)	10 (1)	13 (1)	14 (1)	19 (1)
	20 (2)	23 (1)	29 (1)	33 (3)	36 (4)	41 (1)	42 (1)	43 (2)	44 (1)	45 (1)	47 (1)
	48 (2)	53 (1)	54 (3)	55 (1)	57 (1)	61 (3)	63 (1)	64 (1)	75 (1)	79 (1)	80 (2)
	81 (1)	84 (2)	85 (1)	86 (1)	87 (1)	88 (1)	90 (2)	95 (1)	96 (1)		
Artocarpus heterophyllus	53 (1)										
Artocarpus hirsutus	89 (1)	100 (1)									
Calophyllum polyanthum	4 (1)	11 (1)	20 (1)	21 (1)	37 (1)	38 (1)	39 (1)	42 (1)	48 (1)		
Canarium strictum	1 (1)										
Cullenia exarillata	2 (4)	3 (1)	4 (1)	5 (2)	6 (3)	7 (1)	8 (1)	10 (2)	11 (2)	12 (4)	13 (3)
	14 (2)	15 (2)	16 (2)	18 (1)	19 (1)	20 (1)	21 (1)	22 (1)	23 (1)	25 (1)	27 (2)
	28 (1)	29 (3)	30 (2)	31 (3)	33 (1)	34 (2)	35 (2)	36 (2)	37 (1)	38 (3)	39 (2)
	40 (1)	41 (4)	42 (2)	43 (4)	44 (2)	46 (5)	47 (4)	48 (2)	49 (1)	50 (1)	53 (1)
Cullenia exarillata	54 (4)	56 (2)	57 (3)	58 (2)	59 (1)	62 (1)	63 (1)	64 (2)	65 (1)	66 (3)	67 (2)
	68 (2)	70 (1)	71 (2)	72 (1)	73 (2)	74 (2)	76 (1)	78 (3)	79 (3)	82 (1)	83 (2)
	84 (1)	85 (1)	86 (1)	87 (1)	88 (1)	89 (2)	90 (2)	91 (1)	92 (3)	93 (1)	94 (1)
	95 (2)										
Dimocarpus longan	5 (1)	10 (2)	12 (1)	18 (1)	32 (1)	36 (1)	69 (1)				
Diospyros bourdillonii	4 (1)	5 (1)	15 (1)	18 (1)	19 (1)	26 (1)	28 (1)	29 (1)	48 (1)	50 (1)	51 (1)
	62 (1)	66 (1)	76 (1)	79 (1)							
Dysoxylum malabaricum	4 (1)	7 (1)	25 (1)	35 (1)	40 (1)	44 (1)	55 (1)	67 (1)	74 (1)		
Elaeocarpus tuberculatus	11 (1)	15 (1)	18 (1)	20 (1)	34 (1)	39 (1)	45 (1)	49 (1)	54 (1)	87 (1)	
Garcinia morella	8 (1)	10 (1)	14 (1)	15 (1)	17 (1)	20 (1)	26 (1)	39 (1)	44 (1)	54 (1)	60 (1)
	61 (1)	62 (2)	81 (1)	88 (2)	90 (1)	91 (1)					
Hopea racophloea	35 (1)	42 (1)									
Hydnocarpus alpina	16 (1)	17 (1)	20 (1)	25 (1)	26 (1)	27 (1)	28 (1)	29 (1)	32 (1)	34 (1)	37 (1)
	41 (1)	43 (1)	46 (1)	52 (1)	55 (2)	58 (1)	59 (1)	60 (2)	61 (1)	67 (1)	71 (1)

	84 (1)	91 (1)	97 (1)	98 (1)							
Knema attenuata	8 (1)	14 (1)	18 (1)	19 (1)	20 (1)	25 (1)	30 (1)	32 (2)	38 (1)	40 (2)	53 (1)
	57 (1)	60 (1)	73 (1)	80 (1)							
Litsea floribunda	29 (1)	33 (1)									
Mangifera indica	36 (1)										
Meiogyne pannosa	15 (1)	28 (1)	47 (1)								
Myristica malabarica	5 (1)	7 (2)	8 (1)	9 (1)	10 (1)	11 (1)	17 (1)	20 (2)	24 (1)	26 (1)	28 (1)
	30 (2)	33 (1)	35 (1)	37 (1)	38 (1)	40 (1)	42 (2)	47 (1)	49 (1)	50 (3)	52 (1)
	53 (3)	54 (3)	55 (1)	58 (1)	61 (2)	63 (2)	66 (1)	71 (1)	73 (1)	74 (2)	75 (1)
	76 (2)	80 (1)	81 (1)	83 (1)	85 (1)	86 (1)	88 (1)	90 (1)			
Palaquium ellipticum	1 (1)	2 (1)	3 (1)	4 (1)	5 (3)	8 (1)	10 (2)	11 (1)	17 (1)	20 (2)	23 (1)
	24 (2)	25 (2)	26 (1)	27 (1)	28 (1)	29 (2)	30 (2)	31 (1)	33 (2)	34 (2)	35 (2)
	36 (2)	37 (2)	39 (1)	41 (2)	43 (1)	45 (1)	46 (1)	49 (2)	50 (1)	51 (1)	52 (3)
	53 (1)	54 (1)	56 (3)	57 (1)	58 (2)	59 (1)	60 (2)	61 (2)	62 (3)	64 (2)	65 (1)
	67 (3)	68 (1)	69 (2)	70 (3)	71 (2)	73 (2)	74 (1)	76 (1)	80 (1)	83 (1)	84 (2)
	85 (2)	86 (1)	94 (1)	95 (2)	96 (1)						
Pavetta hispidula	59 (1)	96 (1)									
Persea macrantha	2 (2)	3 (2)	4 (2)	5 (1)	9 (1)	18 (1)	20 (1)	25 (1)	26 (1)	31 (1)	32 (1)
	34 (1)	38 (1)	43 (1)	45 (1)	49 (1)	55 (1)	58 (2)	60 (1)	61 (1)	73 (1)	76 (1)
	81 (1)	82 (1)	89 (1)								
Psychotria nigra	59 (1)	70 (1)									
Syzygium hemisphericum	24 (1)	50 (1)									
Syzygium laetum	22 (1)	33 (1)	38 (1)	39 (1)	48 (1)	58 (1)	73 (1)				

Appendix 1.6. Occurrence of saplings (gbh 10.1-30.0 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Silent valley, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Aglaia elaeagnoidea	26 (1)										
Agrostistachys borneensis	7 (1)	11 (1)	12 (1)	21 (2)	23 (1)	24 (1)	26 (2)	29 (3)	30 (2)	31 (1)	33 (5)
	34 (1)	36 (2)	42 (2)	44 (1)	47 (1)	48 (3)	49 (1)	53 (2)	54 (6)	60 (1)	62 (2)
	63 (2)	64 (7)	65 (4)	66 (4)	71 (1)	72 (5)	74 (1)	75 (2)	76 (8)	79 (3)	80 (1)
	82 (2)	85 (1)	87 (3)	88 (3)	89 (1)	94 (2)	95 (3)	96 (3)	97 (1)	99 (2)	100 (1)
Cullenia exarillata	1 (4)	2 (3)	3 (1)	6 (4)	7 (6)	9 (2)	10 (1)	12 (3)	14 (2)	15 (3)	16 (4)
	17 (2)	18 (1)	19 (6)	20 (3)	21 (1)	22 (2)	24 (2)	26 (4)	27 (2)	28 (1)	29 (1)
	30 (3)	31 (2)	32 (3)	33 (2)	34 (2)	35 (1)	36 (1)	37 (3)	38 (1)	39 (1)	40 (2)
	42 (1)	43 (2)	44 (2)	47 (1)	48 (1)	49 (1)	51 (1)	52 (3)	54 (1)	55 (4)	57 (3)
	60 (2)	62 (2)	63 (4)	64 (1)	65 (2)	67 (3)	68 (3)	69 (1)	70 (2)	71 (2)	72 (4)
	73 (3)	74 (3)	75 (1)	78 (1)	79 (1)	81 (3)	83 (4)	84 (1)	87 (1)	89 (2)	90 (3)
	91 (1)	93 (1)	96 (2)	97 (2)	98 (1)	99 (1)	100 (1)				
Dimocarpus longan	8 (1)	9 (1)	13 (1)	18 (1)	21 (1)	22 (2)	23 (1)	25 (1)	29 (1)	34 (1)	46 (1)
	52 (1)	53 (1)	55 (1)	84 (1)	93 (1)	98 (1)					
Diospyros bourdillonii	3 (1)	5 (4)	7 (2)	8 (2)	11 (2)	13 (6)	14 (2)	15 (2)	16 (3)	17 (3)	18 (1)
	20 (1)	21 (1)	23 (2)	25 (3)	26 (2)	27 (1)	29 (1)	32 (1)	33 (2)	35 (1)	36 (2)
	37 (2)	38 (1)	42 (1)	47 (2)	53 (1)	54 (4)	56 (1)	63 (1)	66 (1)	71 (1)	72 (1)
	73 (1)	74 (1)	75 (1)	78 (2)	79 (1)	90 (3)	91 (2)	92 (1)	93 (1)	95 (1)	96 (3)
	98 (1)	100 (2)									
Dysoxylum malabaricum	3 (1)	8 (1)	18 (1)	19 (1)	21 (1)	27 (1)	30 (1)	32 (1)	41 (1)	47 (1)	55 (1)
	97 (1)										
Elaeocarpus tuberculatus	11 (1)	17 (1)	22 (1)	27 (1)	31 (1)	37 (1)					
Garcinia morella	9 (3)	11 (1)	12 (1)	14 (1)	15 (2)	16 (1)	19 (3)	23 (2)	26 (1)	28 (1)	29 (2)
	32 (1)	33 (1)	34 (2)	35 (3)	37 (3)	45 (1)	46 (2)	47 (4)	51 (3)	60 (1)	61 (2)
	62 (1)	63 (2)	66 (1)	67 (1)	68 (1)	69 (1)	72 (2)	73 (2)	74 (2)	75 (1)	77 (4)
	78 (1)	80 (4)	83 (1)	84 (3)	85 (2)	86 (1)	87 (2)	89 (2)	90 (1)	91 (2)	92 (3)
	93 (2)	96 (2)									
Hopea racophloea	28	40	48	4							

	(1)	(1)	(1)	(1)							
Hydnocarpus alpina	14 (1)	15 (1)	23 (2)	26 (1)	28 (1)	31 (1)	33 (1)	34 (1)	36 (1)	40 (1)	46 (1)
	48 (1)	50 (1)	51 (1)	53 (1)	54 (1)	59 (1)	62 (1)	66 (1)	69 (1)	74 (1)	81 (1)
	88 (1)	92 (1)	97 (1)	100 (1)							
Knema attenuata	7 (1)	16 (1)	18 (1)	21 (2)	22 (1)	23 (1)	24 (1)	30 (1)	31 (1)	32 (1)	40 (1)
	42 (1)	44 (1)	47 (1)	48 (1)	49 (2)	50 (1)	51 (1)	54 (1)	62 (1)	63 (1)	76 (1)
	86 (1)										
Mallotus philippensis	19 (1)	58 (1)									
Mangifera indica	41 (1)	51 (1)									
Meiogyne pannosa	2 (1)	9 (1)	12 (1)	17 (1)	18 (1)	19 (1)	31 (1)	32 (3)	33 (3)	34 (2)	35 (1)
	36 (1)	40 (1)	41 (1)	42 (1)	44 (1)	46 (1)	49 (1)	50 (2)	51 (1)	52 (1)	53 (1)
	55 (1)	56 (1)	59 (1)	61 (1)	66 (1)	69 (2)	70 (1)	71 (1)	73 (1)	76 (1)	83 (1)
	84 (1)	85 (1)	87 (1)	88 (1)	92 (1)						
Myristica malabarica	1 (1)	6 (1)	8 (2)	10 (1)	12 (2)	13 (1)	18 (1)	19 (1)	20 (5)	21 (1)	22 (1)
	23 (3)	24 (2)	25 (1)	29 (4)	31 (4)	33 (2)	34 (2)	39 (3)	42 (1)	43 (1)	45 (1)
	46 (2)	47 (2)	49 (2)	52 (1)	55 (3)	56 (1)	58 (1)	59 (1)	61 (1)	62 (1)	76 (1)
	78 (1)	91 (1)	93 (1)								
Palaquium ellipticum	3 (2)	6 (1)	9 (1)	10 (2)	11 (1)	12 (1)	13 (1)	15 (1)	18 (3)	19 (3)	20 (2)
	22 (3)	23 (3)	25 (1)	26 (3)	28 (2)	29 (3)	30 (1)	31 (2)	32 (2)	33 (3)	34 (1)
	38 (7)	39 (1)	41 (2)	42 (3)	43 (1)	44 (4)	45 (2)	47 (1)	48 (1)	49 (1)	50 (4)
	51 (1)	52 (5)	54 (1)	55 (1)	56 (1)	58 (2)	59 (1)	61 (1)	62 (3)	63 (1)	65 (1)
	68 (1)	69 (1)	70 (1)	71 (2)	73 (1)	74 (1)	76 (5)	78 (2)	82 (1)	87 (2)	88 (2)
	89 (2)	90 (1)	91 (1)	93 (1)	97 (3)	99 (1)	100 (2)				
Pavetta hispidula	58 (2)	61 (1)	62 (2)	73 (1)	75 (1)	82 (1)	92 (1)				
Persea macrantha	11 (1)	12 (1)	15 (1)	19 (1)	21 (1)	23 (1)	30 (1)	37 (1)	71 (1)	79 (1)	
Psychotria nigra	33 (1)	35 (1)	48 (3)	49 (1)	51 (1)	52 (1)	53 (1)	56 (1)	57 (1)	59 (2)	60 (2)
	62 (2)	69 (2)	70 (1)	71 (1)	73 (1)	74 (2)	77 (1)	80 (1)	83 (1)	86 (1)	87 (1)
	89 (1)	93 (2)									
Syzygium hemisphericum	7 (2)	9 (3)	10 (1)	11 (1)	12 (1)	25 (1)	26 (1)	31 (1)	52 (1)	100 (1)	
Syzygium laetum	5 (1)	6 (1)	7 (1)	10 (1)	12 (1)	17 (1)	19 (1)	20 (2)	21 (2)	22 (3)	23 (1)
	27 (1)	30 (1)	34 (2)	39 (1)	41 (2)	45 (1)	46 (1)	47 (3)	49 (1)	50 (1)	54 (1)

	58 (1)	59 (1)	62 (1)	63 (2)	66 (1)	67 (1)	70 (4)	74 (1)	75 (1)	77 (1)	79 (1)
	84 (1)	86 (1)	91 (1)	98 (1)	100 (1)						

Appendix 1.7. Occurrence of mature trees (gbh> 30.1 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Vazhachal, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Aporosa acuminata	9 (1)	11 (1)	17 (1)	28 (2)	52 (1)	96 (1)					
Artocarpus heterophyllus	69 (1)										
Artocarpus hirsutus	2 (1)	28 (1)	51 (1)	55 (1)	73 (1)	86 (1)	92 (1)				
Baccaurea courtallensis	28 (1)	60 (1)	62 (1)								
Calophyllum polyanthum	64 (1)										
Canarium strictum	58 (1)										
Cinnamomum malabatrum	3 (1)	49 (1)									
Dimocarpus longan	4 (1)	10 (3)	22 (1)	31 (1)	37 (1)	39 (1)	43 (1)	61 (1)	69 (1)	81 (1)	
Dysoxylum malabaricum	12 (1)										
Holigarna arnottiana	5 (1)	59 (1)	66 (1)	69 (1)	70 (2)	88 (1)	89 (1)	92 (2)	94 (2)		
Holigarna grahamii	26 (1)	28 (2)									
Hopea parviflora	27 (1)										
Hydnocarpus pentandra	6 (1)	8 (1)	17 (1)	21 (1)	34 (1)	52 (2)	54 (1)	57 (1)	58 (1)	60 (1)	74 (1)
	77 (2)	86 (2)	88 (1)	89 (2)	90 (2)	91 (2)	92 (2)	96 (1)			
Ixora brachiata	10 (1)	21 (1)	28 (1)	54 (1)	89 (1)	92 (1)					
Knema attenuata	1 (1)	4 (1)	5 (3)	6 (2)	7 (1)	13 (1)	14 (3)	15 (2)	16 (1)	19 (1)	20 (1)
	22 (1)	23 (4)	24 (1)	25 (3)	26 (3)	27 (1)	28 (1)	31 (1)	32 (1)	34 (1)	36 (2)
	37 (4)	38 (1)	39 (1)	40 (1)	41 (2)	42 (1)	43 (2)	44 (1)	45 (5)	46 (2)	47 (1)
	52 (2)	54 (2)	55 (1)	56 (2)	57 (1)	58 (1)	59 (1)	60 (2)	61 (1)	62 (1)	63 (1)
	64 (4)	66 (2)	67 (1)	73 (2)	74 (1)	76 (2)	77 (1)	78 (2)	79 (3)	80 (2)	82 (4)
	83 (2)	85 (2)	86 (1)	87 (2)	88 (2)	89 (1)	91 (1)	92 (1)	93 (2)	94 (1)	95 (3)
	97 (3)	98 (4)	99 (2)	100 (1)							
Mallotus philippensis	31 (2)	47 (1)	50 (1)	57 (1)	71 (1)	84 (1)	86 (1)	96 (1)	97 (1)		
Mangifera indica	87 (1)										
Melicope lunu-ankenda	22 (1)	39 (1)	49 (1)	50 (1)	52 (1)	88 (1)					

Memecylon talbotianum	3 (1)	20 (1)	58 (1)	91 (1)							
Myristica malabarica	1 (1)	12 (1)	14 (1)	18 (1)	24 (2)	31 (1)	36 (1)	38 (3)	39 (1)	43 (1)	44 (1)
	55 (1)	59 (1)	62 (1)	64 (1)	65 (2)	66 (1)	76 (1)	79 (1)	92 (1)	100 (1)	
Otonephelium stipulaceum	36 (1)	37 (1)									
Polyalthia coffeoides	1 (3)	2 (1)	3 (1)	4 (1)	9 (1)	11 (1)	16 (1)	19 (2)	21 (1)	28 (1)	30 (1)
	32 (2)	50 (1)	66 (1)	68 (2)	69 (2)	70 (2)	71 (2)	79 (1)	90 (1)	91 (1)	94 (1)
	95 (1)	96 (3)									
Pterospermum reticulatum	1 (1)	10 (1)									
UNV 1	3 (1)	11 (1)	19 (1)	20 (1)	26 (1)	83 (1)	89 (1)				
UNV 2	7 (1)	15 (1)	24 (1)	85 (1)	88 (1)						
UNV 3	3 (1)	5 (1)	12 (1)	13 (1)	28 (1)	55 (1)	80 (1)	87 (1)	95 (1)		
UNV 4	10 (1)	11 (1)	22 (1)	90 (1)	98 (1)						
UNV 5	12 (3)	18 (1)	25 (1)	26 (1)	48 (1)	58 (1)	61 (1)	79 (1)	88 (1)	91 (1)	

Appendix 1.8. Occurrence of saplings (gbh 10.1-30.0 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Vazhachal, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Aporosa acuminata	1 (1)	6 (2)	7 (3)	8 (3)	10 (5)	11 (6)	12 (5)	13 (1)	14 (2)	15 (2)	16 (1)
	18 (1)	21 (1)	24 (1)	27 (3)	28 (1)	29 (7)	30 (3)	31 (3)	32 (12)	33 (3)	34 (2)
	35 (3)	39 (2)	41 (1)	42 (1)	43 (2)	44 (6)	46 (2)	48 (1)	49 (7)	50 (9)	51 (14)
	52 (5)	53 (14)	54 (1)	55 (2)	56 (1)	57 (2)	58 (1)	66 (1)	67 (7)	68 (9)	69 (6)
	70 (9)	71 (13)	72 (4)	74 (3)	75 (6)	76 (1)	77 (2)	78 (1)	79 (1)	80 (1)	81 (2)
	84 (1)	85 (8)	86 (6)	87 (4)	88 (1)	89 (2)	91 (3)	92 (2)	93 (1)	95 (1)	96 (6)
	97 (2)	98 (6)	99 (1)								
Artocarpus hirsutus	48 (1)										
Baccaurea courtallensis	1 (1)	22 (1)	26 (1)	27 (1)	45 (1)	77 (1)	98 (1)				
Cinnamomum malabatrum	51 (3)	70 (1)	72 (1)								
Dimocarpus longan	5 (1)	12 (1)	20 (1)	30 (1)	31 (1)	39 (1)	56 (1)	66 (1)	70 (1)	71 (1)	72 (1)
	73 (1)	84 (1)	98 (1)								
Diospyros buxifolia	26	31	32	64	69	71	72	73	77	84	91

	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Dysoxylum malabaricum	26 (1)	27 (1)	30 (1)	45 (1)	72 (1)						
Garcinia morella	4 (1)	19 (1)									
Holigarna arnottiana	5 (1)	93 (1)									
Hopea parviflora	23 (1)										
Hydnocarpus pentandra	10 (1)	11 (1)	14 (2)	18 (1)	24 (1)	29 (2)	30 (5)	31 (1)	43 (1)	44 (2)	45 (1)
	46 (1)	49 (1)	50 (2)	55 (1)	61 (1)	65 (1)	68 (1)	70 (2)	72 (2)	73 (1)	74 (1)
	75 (2)	78 (1)	81 (2)	85 (1)	86 (1)	87 (1)	89 (1)	93 (1)	96 (1)	97 (2)	
Knema attenuata	5 (1)	30 (2)	42 (1)	75 (3)	81 (1)	84 (1)	85 (1)	97 (1)			
Mallotus philippensis	10 (1)	31 (3)	46 (1)	47 (1)	48 (1)	49 (1)	58 (1)	72 (1)	73 (2)	77 (1)	92 (1)
	93 (1)										
Mangifera indica	86 (1)										
Melicope lunu-ankenda	27 (1)	31 (1)	32 (1)	33 (1)	34 (1)	35 (1)	38 (1)	45 (3)	48 (1)	49 (1)	50 (1)
	54 (3)	55 (1)	57 (1)	65 (1)	66 (1)	74 (1)	77 (1)	93 (3)	95 (1)	97 (1)	98 (1)
Memecylon talbotianum	2 (1)	12 (1)	13 (1)	19 (1)	21 (1)	50 (1)	62 (1)	71 (1)			
Myristica malabarica	20 (1)										
Nothopegia travancorica	71 (1)	77 (1)	80 (1)	84 (2)	86 (1)	93 (2)	97 (1)				
Polyalthia coffeoides	6 (2)	9 (3)	10 (3)	11 (1)	13 (2)	16 (1)	21 (1)	29 (2)	30 (4)	31 (1)	35 (2)
	40 (1)	46 (1)	47 (1)	50 (1)	51 (1)	57 (2)	59 (1)	61 (1)	63 (3)	65 (2)	66 (5)
	67 (2)	68 (3)	69 (2)	70 (2)	71 (6)	73 (4)	80 (1)	81 (6)	82 (1)	83 (3)	84 (2)
	86 (1)	87 (6)	88 (3)	89 (2)	90 (1)	91 (4)	92 (6)	93 (4)	94 (4)	95 (1)	96 (4)
	97 (3)	98 (1)	99 (2)	100 (4)							
Tabernaemontana alternifolia	84 (1)										
UNV 1	1 (1)	2 (1)	6 (1)	10 (1)							
UNV 2	1 (1)	3 (1)	11								
UNV 3	8 (1)	42 (1)									
UNV 4	9 (1)	17 (1)									

Appendix 1.9. Occurrence of mature trees (gbh> 30.1 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Kallipara, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Alstonia scholaris	5 (1)										
Cassia fistula	3 (1)	4 (1)	11 (1)	12 (1)	30 (1)	31 (1)	35 (1)	38 (1)	49 (2)	53 (2)	56 (1)
	59 (1)	62 (1)	73 (1)	76 (1)	78 (1)	79 (1)	90 (1)	91 (2)	94 (1)		
Catunaregam spinosa	22 (1)	24 (1)	67 (1)	76 (1)							
Dalbergia latifolia	23 (1)	45 (1)									
Dillenia pentagyna	1 (1)	2 (1)	11 (1)	18 (1)	21 (1)	27 (1)	28 (1)	30 (1)	37 (2)	40 (1)	41 (2)
	44 (1)	45 (1)	49 (1)	71 (2)	72 (2)	86 (1)	91 (1)	92 (1)	93 (1)	96 (1)	98 (1)
	99 (1)										
Grewia tiliifolia	1 (1)	4 (1)	34 (1)	36 (1)	40 (1)	43 (1)	66 (1)	76 (1)	81 (2)	87 (2)	89 (1)
	91 (1)	92 (2)									
Haldina cordifolia	1 (1)	4 (2)	80 (1)	85 (1)							
Lagerstroemia microcarpa	2 (3)	7 (1)	8 (1)	19 (1)	21 (1)	36 (1)	39 (1)	44 (1)	47 (1)	50 (2)	51 (1)
	54 (1)	57 (1)	61 (2)	63 (1)	65 (1)	74 (1)	83 (1)	85 (1)	86 (1)	88 (1)	93 (1)
	96 (2)	99 (2)	100 (1)								
Macaranga peltata	10 (1)	20 (1)	36 (1)	41 (1)	47 (1)						
Olea dioica	13 (1)										
Tabernaemontana alternifolia	5 (1)	6 (4)	13 (2)	28 (1)	31 (1)						
Tectona grandis	43 (1)	90 (2)									
Terminalia bellirica	56 (1)	89 (1)									
Terminalia paniculata	2 (2)	3 (1)	4 (1)	5 (1)	7 (1)	8 (1)	12 (1)	13 (1)	14 (2)	18 (2)	24 (2)
	25 (2)	26 (3)	27 (1)	29 (1)	30 (1)	33 (1)	35 (2)	38 (1)	39 (1)	40 (1)	41 (1)
	42 (1)	43 (1)	46 (1)	47 (1)	48 (1)	51 (1)	54 (1)	56 (1)	57 (1)	58 (1)	60 (1)
	62 (1)	64 (1)	65 (1)	68 (1)	71 (1)	73 (1)	75 (1)	77 (2)	82 (2)	88 (2)	95 (3)
	96 (1)	97 (3)	98 (1)	100 (1)							
UNK	23 (1)										
UNK1	3 (1)										

UNK2	4 (1)	5 (1)									
UNK5	14 (1)										
Wrightia tinctoria	4 (1)	29 (1)	39 (1)	54 (1)	56 (1)	62 (1)					
Ziziphus xylopyrus	6 (1)	10 (1)									

Appendix 1.10. Occurrence of saplings (gbh 10.1-30.0 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Kallipara, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Alstonia scholaris	8 (1)										
Cassia fistula	1 (1)	6 (1)	10 (1)	12 (1)	15 (3)	22 (2)	33 (1)	34 (1)	37 (2)	44 (1)	56 (2)
	58 (1)	69 (1)	70 (1)	86 (1)							
Catunaregam spinosa	4 (2)	5 (1)	16 (3)	17 (1)	22 (1)	23 (1)	32 (2)	46 (1)	52 (1)	67 (1)	78 (1)
	85 (1)	98 (1)									
Dillenia pentagyna	100 (1)										
Diospyros cordifolia	23 (1)	25 (1)	34 (1)	38 (1)	39 (1)	44 (1)	59 (1)	73 (1)	83 (1)		
Grewia tiliifolia	19 (1)	63 (1)									
Lagerstroemia microcarpa	1 (1)										
Mallotus philippensis	25 (1)										
Tabernaemontana alternifolia	11 (1)	13 (1)	23 (1)	53 (1)	81 (1)						
Terminalia paniculata	3 (3)	9 (1)	11 (1)	20 (1)	31 (1)	32 (1)	33 (2)	34 (1)	48 (1)	49 (1)	66 (1)
	69 (1)										
UNK	17 (1)										
UNK1	2 (1)	3 (1)	5 (2)	11 (1)							
Wrightia tinctoria	36 (1)	51 (1)	70 (1)								

Appendix 1.11. Occurrence of mature trees (gbh> 30.1 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Muthikulam, Siruvani, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Actinodaphne salicina	16 (1)	29 (1)	33 (2)	41 (1)	46 (3)	48 (1)	53 (1)	55 (1)	57 (1)	84 (1)	100 (1)
Aglaia lawii	1 (1)	5 (3)	8 (1)	13 (1)	15 (1)	16 (1)	28 (1)	34 (1)	35 (1)	39 (1)	40 (1)
	41 (1)	42 (1)	44 (1)	55 (1)	60 (1)	61 (2)	68 (1)	72 (1)	80 (2)	87 (1)	91 (1)
Agrostistachys borneensis	1 (1)	2 (3)	11 (2)	13 (1)	16 (1)	17 (1)	20 (8)	21 (1)	23 (1)	25 (1)	26 (1)
	27 (1)	29 (3)	30 (2)	31 (1)	34 (2)	35 (1)	36 (1)	38 (3)	40 (1)	45 (5)	46 (1)
	47 (1)	50 (1)	51 (1)	53 (1)	54 (1)	55 (2)	56 (2)	58 (1)	60 (1)	61 (1)	63 (1)
	64 (1)	66 (1)	72 (1)	73 (1)	74 (1)	76 (1)	77 (4)	78 (1)	80 (1)	81 (2)	83 (1)
	84 (3)	87 (1)	88 (1)	94 (1)	96 (1)	97 (2)	98 (1)	100 (3)			
Antidesma montanum	11 (1)	71 (1)									
Canarium strictum	4 (1)										
Cinnamomum macrocarpum	17 (1)	73 (1)									
Cinnamomum malabatrum	95 (1)										
Cullenia exarillata	1 (2)	2 (1)	6 (1)	7 (1)	18 (1)	31 (1)	32 (1)	34 (1)	40 (2)	42 (2)	43 (1)
	44 (1)	49 (1)	51 (3)	65 (1)	71 (1)	72 (1)	73 (2)	74 (2)	75 (1)	77 (1)	78 (1)
	79 (1)	81 (1)	88 (1)	91 (1)	100 (1)						
Dimocarpus longan	27 (1)										
Diospyros assimilis	17 (1)	21 (1)	23 (1)	26 (1)	29 (1)	32 (2)	33 (1)	50 (2)	51 (2)	68 (1)	71 (1)
	72 (1)	73 (1)	85 (1)	88 (2)	89 (2)	92 (1)	95 (1)	96 (3)			
Diospyros trichophylla	100 (1)										
Drypetes venusta	10 (1)	11 (1)									
Drypetes wightii	8 (1)	9 (1)	10 (1)	26 (1)	28 (1)	29 (1)	36 (1)	40 (1)	44 (1)	47 (1)	48 (1)
	52 (1)	59 (2)	60 (1)	61 (2)	62 (2)	65 (1)	66 (1)	69 (1)	73 (1)	76 (1)	79 (2)
	81 (1)	85 (1)	91 (1)	92 (1)	98 (1)	99 (2)	100 (1)				
Garcinia morella	2 (1)	7 (1)	12 (1)	18 (1)	23 (1)	30 (1)	33 (1)	38 (4)	39 (2)	40 (1)	41 (2)
	43 (1)	44 (1)	46 (1)	48 (1)	49 (1)	69 (1)	70 (1)	73 (1)	75 (2)	76 (2)	77 (1)
	82 (1)	89 (2)	90 (1)	91 (2)	92 (2)	93 (1)	97 (2)	98 (1)	100 (2)		

Gomphandra tetrandra	19 (1)										
Heritiera papilio	24 (1)	31 (1)	36 (1)	43 (1)	45 (1)	89 (1)					
Holigarna arnottiana	20 (1)	33 (1)	64 (1)	92 (1)	99 (1)						
Holigarna grahamii	74 (1)	82 (1)	84 (1)								
Hydnocarpus pentandra	10 (1)	56 (1)	59 (1)	60 (1)							
Knema attenuata	1 (2)	4 (1)	10 (2)	11 (1)	12 (1)	13 (2)	21 (2)	22 (2)	25 (1)	26 (1)	27 (2)
	29 (2)	30 (2)	31 (1)	32 (1)	36 (2)	38 (2)	41 (1)	42 (1)	43 (1)	48 (2)	54 (1)
	57 (1)	58 (1)	61 (3)	63 (1)	66 (1)	67 (1)	70 (1)	71 (1)	73 (1)	76 (1)	80 (2)
	84 (2)	85 (2)	86 (1)	87 (1)	88 (1)	91 (1)	92 (1)	94 (1)	97 (1)	98 (1)	100 (1)
Litsea floribunda	17 (1)	51 (1)	56 (1)	59 (3)	63 (1)	76 (1)	78 (1)	83 (1)	98 (2)		
Macaranga peltata	28 (1)	32 (1)	37 (2)	38 (1)	46 (1)	55 (1)	60 (1)	62 (1)			
Mangifera indica	34 (1)	58 (1)									
Mesua ferrea	13 (1)	21 (1)	32 (1)	52 (1)	60 (1)	61 (1)	71 (1)	82 (1)	86 (1)	92 (1)	97 (2)
Myristica malabarica	4 (1)	5 (1)	12 (1)	18 (1)	19 (2)	20 (1)	28 (2)	34 (2)	38 (1)	39 (1)	40 (1)
	45 (3)	50 (2)	51 (1)	55 (1)	56 (3)	60 (1)	61 (1)	65 (1)	66 (2)	69 (1)	73 (2)
	74 (1)	89 (1)	95 (2)	97 (1)	99 (2)	100 (1)					
Nothopegia racemosa	92 (1)										
Oreocnide integrifolia	3 (1)										
Palaquium ellipticum	1 (1)	5 (1)	6 (1)	7 (2)	8 (2)	13 (1)	14 (3)	16 (3)	22 (2)	25 (1)	26 (1)
	28 (1)	29 (1)	30 (1)	31 (1)	32 (1)	35 (3)	37 (2)	38 (1)	39 (1)	41 (2)	42 (2)
	44 (1)	45 (2)	46 (3)	47 (1)	48 (2)	50 (2)	51 (2)	52 (1)	58 (1)	60 (2)	62 (2)
	64 (2)	65 (1)	66 (1)	67 (2)	69 (1)	70 (1)	72 (2)	73 (2)	74 (3)	78 (1)	79 (1)
	80 (1)	81 (1)	85 (1)	86 (3)	87 (1)	88 (2)	90 (1)	92 (1)	95 (1)	96 (4)	97 (1)
Paracroton pendulus	17 (1)	29 (2)	42 (1)	44 (1)	62 (1)	63 (1)	64 (1)	73 (1)	86 (1)	92 (1)	96 (1)
	98 (1)	99 (1)									
Phoebe lanceolata	42 (1)	43 (1)	52 (1)	59 (1)	62 (1)	80 (1)	90 (1)	98 (1)			
Poeciloneuron indicum	10 (1)	16 (1)	28 (1)								
Polyalthia coffeoides	1 (1)	3 (1)	5 (2)	17 (1)	19 (1)	20 (1)	31 (1)	33 (1)	35 (1)	41 (1)	51 (1)
	55 (1)	60 (1)	72 (1)	74 (1)	75 (1)	76 (1)	80 (1)	82 (1)	84 (1)	87 (2)	90 (1)
	91 (1)	97 (1)	99 (1)	100 (2)							

Syzygium gardneri	1 (1)	6 (1)	12 (1)	30 (1)	59 (1)						
Syzygium hemisphericum	37 (1)										
Syzygium laetum	20 (2)	30 (1)	39 (1)	40 (1)	45 (1)	57 (1)	63 (1)	64 (1)	68 (1)	72 (1)	83 (1)
	89 (1)	91 (1)	93 (1)								
Syzygium mundagam	2 (1)	24 (1)	25 (1)	65 (1)	87 (1)						
Syzygium munronii	37 (1)	41 (1)	44 (1)	47 (1)							
UN S 1	23 (1)										
Xanthophyllum arnottianum	9 (1)	50 (1)	61 (1)	70 (1)	81 (1)						

Appendix 1.12. Occurrence of saplings (gbh 10.1-30.0 cm) of different species in quadrats (10m x 10m) laid out in the 1-ha permanent plot established at Siruvani, Kerala. Values in parentheses are number of individuals in the given quadrat.

Species	Quadrat number										
Actinodaphne salicina	8 (1)	18 (1)	26 (1)	32 (1)	36 (3)	38 (1)	46 (1)	52 (1)	53 (1)	54 (1)	55 (1)
	56 (3)	57 (1)	58 (2)	62 (1)	74 (1)	76 (1)	85 (1)	89 (1)			
Aglaia lawii	6 (1)	7 (1)	12 (1)	18 (2)	19 (2)	20 (1)	25 (2)	26 (1)	33 (4)	34 (2)	35 (2)
	36 (1)	37 (1)	38 (4)	39 (1)	43 (2)	54 (1)	55 (1)	59 (1)	62 (2)	63 (3)	70 (3)
	71 (3)	80 (1)	82 (1)	88 (1)	89 (1)	92 (1)	93 (1)	100 (1)			
Agrostistachys borneensis	1 (1)	2 (3)	18 (1)	19 (1)	23 (2)	25 (1)	36 (1)	39 (3)	42 (4)	43 (7)	44 (3)
	47 (1)	52 (1)	55 (2)	58 (1)	59 (4)	61 (4)	62 (1)	64 (1)	81 (1)	86 (1)	91 (1)
	98 (1)	100 (1)									
Antidesma montanum	3 (1)	23 (1)	28 (1)	31 (1)	40 (1)	49 (1)	73 (1)	82 (1)			
Aphanamixis polystachya	4 (1)	6 (1)	24 (1)	26 (1)	27 (1)	36 (2)	38 (1)	43 (2)	60 (1)	62 (1)	66 (1)
Artocarpus heterophyllus	3 (1)										
Artocarpus hirsutus	60 (1)										
Baccaurea courtallensis	3 (1)	21 (1)	34 (1)	38 (1)	65 (1)	66 (1)					
Canarium strictum	8 (1)	16 (1)	33 (1)	42 (1)	73 (1)						
Cinnamomum macrocarpum	24 (1)										
Cullenia exarillata	4 (1)	5 (1)	8 (3)	9 (1)	10 (1)	16 (1)	19 (1)	21 (1)	22 (1)	23 (1)	28 (1)
	30 (1)	32 (1)	33 (1)	39 (1)	41 (1)	42 (4)	43 (3)	44 (3)	45 (1)	46 (1)	48 (1)
	51 (1)	52 (2)	53 (2)	54 (4)	55 (1)	56 (1)	57 (2)	58 (1)	60 (4)	61 (1)	63 (1)

	64 (1)	66 (1)	76 (2)								
Dimocarpus longan	20 (1)	23 (1)	46 (1)	51 (1)	77 (1)						
Diospyros assimilis	7 (1)	11 (1)	15 (1)	18 (2)	26 (1)	27 (2)	28 (1)	30 (1)	31 (1)	35 (1)	36 (1)
	37 (1)	38 (3)	39 (1)	41 (1)	42 (2)	43 (5)	44 (1)	46 (2)	50 (1)	58 (1)	59 (1)
	60 (2)	61 (1)	62 (2)	72 (1)	73 (1)	74 (1)	76 (1)	82 (1)	86 (1)	90 (1)	91 (2)
	95 (1)										
Diospyros trichophylla	8 (1)	41 (1)	69 (1)								
Drypetes venusta	21 (1)										
Drypetes wightii	6 (1)	8 (2)	14 (1)	36 (1)	37 (1)	38 (1)	39 (1)	40 (2)	45 (2)	49 (3)	60 (1)
	63 (1)	83 (1)	88 (1)	89 (1)	92 (1)	95 (1)					
Flacourtia montana	39 (1)										
Garcinia morella	4 (1)	6 (2)	7 (5)	9 (1)	10 (1)	12 (4)	13 (7)	14 (5)	16 (3)	18 (2)	19 (1)
	21 (1)	22 (2)	23 (2)	24 (1)	26 (1)	28 (2)	30 (2)	31 (1)	32 (5)	33 (2)	34 (2)
	35 (3)	36 (1)	37 (5)	38 (3)	39 (3)	40 (1)	41 (1)	43 (1)	44 (2)	45 (3)	47 (2)
	48 (4)	49 (1)	50 (2)	51 (3)	52 (2)	53 (4)	54 (2)	55 (5)	56 (3)	57 (1)	62 (3)
	63 (1)	66 (1)	67 (1)	68 (1)	70 (2)	71 (3)	72 (1)	73 (1)	75 (1)	76 (1)	77 (2)
	78 (1)	79 (2)	80 (1)	81 (2)	82 (1)	83 (2)	86 (2)	88 (1)	89 (1)	92 (3)	93 (3)
	94 (2)	95 (1)	96 (1)	98 (1)							
Gomphandra tetrandra	2 (2)	3 (1)	7 (4)	8 (2)	9 (2)	18 (1)	21 (1)	22 (1)	23 (1)	24 (1)	26 (1)
	27 (3)	31 (1)	32 (1)	36 (2)	38 (4)	39 (2)	43 (1)	45 (1)	56 (2)	57 (1)	61 (3)
	65 (1)	66 (2)	67 (3)	72 (1)	74 (1)	77 (1)	78 (1)	80 (1)	82 (1)	83 (1)	85 (1)
	86 (1)	87 (1)	89 (1)	90 (2)	92 (1)	93 (1)	98 (2)	100 (1)			
Heritiera papilio	19 (1)	42 (1)	44 (2)	47 (1)	50 (1)	55 (1)	57 (1)	60 (1)	62 (2)	66 (1)	77 (1)
Holigarna arnottiana	5 (1)	20 (1)	24 (1)	36 (1)	97 (1)	98 (1)					
Holigarna grahamii	58 (1)	66 (1)	82 (2)	83 (1)	84 (1)						
Hydnocarpus pentandra	4 (1)	6 (1)	41 (1)	45 (1)	59 (2)	60 (3)	66 (1)	67 (1)	70 (1)	76 (1)	
Ixora brachiata	39 (1)	49 (1)	78 (1)	83 (1)	95 (1)						
Knema attenuata	2 (1)	3 (2)	5 (2)	8 (1)	10 (1)	14 (5)	15 (1)	16 (4)	18 (1)	19 (1)	21 (1)
	24 (1)	25 (1)	26 (1)	27 (1)	28 (2)	29 (3)	32 (1)	33 (2)	34 (1)	35 (1)	36 (3)
	37 (1)	38 (2)	40 (1)	41 (3)	43 (4)	44 (1)	45 (1)	46 (1)	47 (3)	48 (1)	49 (1)
	50 (3)	51 (4)	56 (1)	60 (1)	61 (2)	62 (1)	65 (1)	68 (1)	70 (2)	73 (1)	76 (3)

	80 (1)	86 (1)	87 (1)	88 (3)	90 (2)	92 (1)	93 (2)	94 (1)	96 (1)	99 (2)	
Litsea floribunda	36 (1)	56 (1)	58 (2)	59 (3)	60 (2)	62 (2)	63 (1)	66 (1)	72 (1)		
Macaranga peltata	19 (1)	62 (1)									
Mastixia arborea	40 (1)	99 (1)									
Meiogyne pannosa	17 (1)	51 (1)	74 (1)	77 (1)	83 (1)						
Mesua ferrea	4 (1)	14 (1)	16 (1)	17 (1)	44 (2)	50 (1)	54 (1)	56 (1)	61 (1)	62 (1)	64 (2)
	65 (1)	73 (1)	77 (1)	81 (2)	89 (1)	92 (1)	98 (1)				
Myristica malabarica	4 (1)	6 (2)	7 (1)	8 (1)	17 (1)	21 (1)	22 (1)	23 (1)	29 (1)	30 (1)	32 (1)
	37 (2)	39 (1)	40 (5)	41 (2)	42 (3)	45 (2)	47 (2)	49 (1)	51 (2)	52 (1)	53 (2)
	58 (1)	59 (4)	60 (3)	61 (1)	63 (2)	64 (1)	66 (4)	67 (1)	73 (2)	76 (1)	77 (1)
	78 (2)	79 (1)	80 (3)	83 (1)	85 (3)	94 (1)	96 (1)	97 (2)	98 (4)		
Nothopegia racemosa	10 (1)	20 (1)	26 (1)	36 (2)	37 (2)	38 (1)	39 (1)	46 (1)	52 (1)	53 (1)	56 (1)
	57 (1)	59 (1)	61 (2)	62 (1)	63 (1)	64 (1)	65 (1)	82 (1)	84 (1)		
Palaquium ellipticum	3 (2)	4 (4)	5 (6)	6 (7)	7 (1)	9 (2)	10 (2)	11 (3)	12 (8)	13 (6)	14 (1)
	15 (3)	17 (4)	18 (3)	19 (1)	21 (2)	22 (1)	23 (2)	24 (2)	25 (1)	26 (3)	27 (4)
	28 (2)	29 (4)	30 (2)	31 (1)	32 (3)	34 (1)	35 (2)	36 (1)	37 (3)	38 (4)	39 (2)
	41 (1)	42 (3)	43 (6)	44 (6)	45 (3)	47 (4)	48 (2)	49 (4)	50 (7)	51 (4)	52 (2)
	53 (1)	54 (5)	55 (4)	56 (3)	57 (2)	58 (6)	60 (2)	61 (8)	62 (5)	63 (4)	65 (1)
	66 (6)	67 (6)	68 (6)	69 (4)	70 (11)	71 (3)	72 (8)	73 (11)	74 (2)	75 (2)	76 (6)
	77 (6)	78 (4)	79 (1)	80 (5)	81 (1)	82 (2)	83 (1)	84 (1)	85 (3)	86 (2)	87 (1)
	88 (1)	89 (1)	90 (1)	91 (1)	92 (1)	94 (3)	95 (1)	96 (1)	98 (2)	99 (1)	100 (1)
Paracroton pendulus	29 (1)	34 (1)	35 (1)	38 (1)	40 (2)	42 (1)	44 (1)	50 (1)	55 (1)	58 (1)	60 (1)
	61 (1)	66 (1)	83 (1)	84 (1)	99 (1)						
Phoebe lanceolata	4 (1)	16 (1)	17 (1)	19 (1)	24 (1)	28 (1)	34 (1)	35 (1)	37 (1)	38 (1)	39 (2)
	42 (3)	44 (2)	46 (1)	49 (1)	56 (1)	57 (4)	58 (1)	59 (2)	61 (1)	62 (1)	63 (1)
	84 (1)	95 (1)									
Polyalthia coffeoides	6 (2)	11 (1)	15 (1)	27 (1)	35 (1)	39 (2)	41 (1)	42 (1)	44 (1)	46 (1)	49 (1)
	50 (1)	53 (1)	56 (2)	62 (1)	63 (1)	68 (1)	81 (1)	84 (1)	86 (1)	89 (2)	90 (1)
Psychotria nigra	39 (1)										
Syzygium gardneri	6 (1)	48 (1)	49 (1)	52 (1)	59 (1)	60 (2)	82 (1)				
Syzygium	17										

hemisphericum	(1)										
Syzygium laetum	7 (3)	15 (1)	16 (1)	19 (1)	20 (1)	23 (2)	25 (1)	26 (2)	30 (2)	31 (1)	35 (2)
	36 (5)	37 (1)	38 (1)	39 (2)	40 (3)	42 (1)	43 (1)	44 (2)	45 (2)	46 (3)	47 (1)
	48 (1)	50 (1)	52 (3)	53 (1)	54 (1)	55 (1)	59 (1)	60 (1)	61 (1)	63 (2)	66 (2)
	71 (2)	74 (1)	76 (1)	77 (1)	81 (2)	87 (1)	90 (1)	91 (1)	95 (1)		
Syzygium mundagam	1 (1)	3 (1)	4 (2)	9 (1)	21 (1)	24 (1)	25 (2)	34 (1)	35 (1)	36 (1)	38 (1)
	39 (4)	42 (2)	44 (2)	46 (1)	47 (1)	54 (3)	61 (3)	65 (1)	72 (1)	83 (1)	85 (1)
	87 (1)	89 (1)	99 (1)								
Syzygium munronii	37 (1)	38 (3)	40 (3)	41 (1)	42 (1)	44 (1)	46 (1)	49 (1)	50 (1)	51 (1)	52 (1)
	53 (1)	55 (1)	57 (2)	66 (1)	68 (1)	71 (1)	72 (1)	75 (1)	76 (2)	77 (1)	80 (1)
	81 (1)	88 (1)	89 (1)								
Trichilia connaroides	35 (1)	40 (1)	45 (1)	51 (1)							
UN S 1	3 (1)										
UN S 2	6 (1)										
UN S 3	6 (1)										
UN S 4	10 (1)										
UN S 5	13 (1)										
UN S 6	28 (1)										
Vepris bilocularis	43 (1)										
Xanthophyllum arnottianum	18 (1)	19 (1)	24 (1)	46 (2)	49 (1)	50 (1)	52 (2)	53 (2)	63 (1)	66 (2)	71 (1)
	75 (2)										


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