PHYTOSOCIOLOGICAL AND EDAPHIC ATTRIBUTES OF FOREST ECOSYSTEMS OF SHENDURNEY WILDLIFE SANCTUARY, KOLLAM, KERALA

By

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(2017-27-006)

THESIS
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DECLARATION

I hereby declare that the thesis entitled "**Phytosociological and edaphic attributes of forest ecosystems of Shendurney wildlife Sanctuary, Kollam, Kerala**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **"Phytosociological and edaphic attributes of forest ecosystems of Shendurney wildlife Sanctuary, Kollam, Kerala"** is a record of research work done independently by **Mr. Halliru Bilyaminu (2017-27-006)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to him.

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Bilyaminu, Halliru.

Dedicated To,

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Wishing him happy retired life

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Introduction

INTRODUCTION

Forest ecosystems of the tropic are regarded as one of the most complex and terrestrial ecosystems of varying complexity, favoring diversity of life forms and possessing exceptional self-maintenance ability. Nevertheless, many of these forest ecosystems fail in their capacity due to intense biotic pressure such as anthropogenic perturbation, climate change, and uncontrolled grazing. Biodiversity conservation has become a considerable charge for the sustainable development of the ecosystem and society. The Western Ghats is considered among the 12 mega-biodiversity centers of the world, characterized by a greater diversity of faunal and floral matches with distinguishing climatic, topographic, and ecological factors, with approximately 18,664 vascular plant taxa, with 5725 endemics (Nayar, 1996). India is a floristically well-heeled country endowed with about 125,000 known species of all organisms and another 400,000 on the verge of apparent exploration (Gadgil and Meher-Homji, 1986). The Asian primary forest, specifically those of the Eastern and the Western Ghats of the Indian peninsula, is disappearing at an unprecedented level due to increasing pressure from humans and either is being substituted by forests containing species that are inferior or changes in the land-use system (Parthasarathy, 1999). Biodiversity is generally interpreted as the number, diversity and the variability of a living organism in a given association, group, or collection (Pearce and Moran, 1994). It is generally recognized by its vast array of faunal, floral, and microorganisms, the genes they produce, and the environment they create. Biological diversity also constitutes the genetic variation within each species - for example, between the collection of crops and animal progeny. Genes, RNA, and DNA-the building blocks of life-determine the difference in character and species. Biodiversity is thus taken into account on three levels: genetic, species, and ecosystem diversity. The ecosystem's function and stability are vital for human survival and economic prosperity (Singh, 2002). Biodiversity forms the heart of the nation's ecological and economic productivity and security (Kandi *et al*., 2011).

The loss of tropical forest biodiversity has resulted from habitat degradation and destruction by unnatural activities, which are now identified as a global issue (Rands *et al.,* 2010). Many areas have prioritized the conservation of biodiversity and landscape productivity in order to restore degraded communities by planting fast-growing, indigenous, and native plant species (Solbrig, 1991). Lovejoy (1980) was considered the pioneer in framing the narrow term biodiversity. Since then, there has been growing concern over the assessment of biodiversity. Biodiversity research has grown in importance as ecologists seek to actively shape global biodiversity in the face of significant perturbations, rates of habitat loss and extinction. Understanding the association between biodiversity and ecosystem functioning is recognized as one of the challenging responsibilities of ecologists (Davis and Richardson, 1995).

Biodiversity inventorying and monitoring are applied at different organizational levels, from genes to ecological systems spatially and temporally, from a smaller area to continents (Heywood, 1997). Thus, the understanding and classification of biological diversity rely significantly on taxonomy, genetics, and ecology. The knowledge of floral and forest taxonomic is very significant for a better understanding and assessing the richness of biodiversity (Jayanthi and Rajendran, 2013). The floristic survey is an exclusive measure of accomplishing the goal. It is acknowledged to be enormous for assessing phytodiversity, managing conservation, and ensuring sustainable utilization.

In the preparatory essay for the Flora Indica, Hooker and Thomson (1855), and then Hooker (1907) at the Imperial Gazetteer of India, assessed the phytogeographical areas of India based on the species-content of the families of all the botanical regions. Hooker (1907) classified British botanical areas of India into the Eastern Himalayas, Gangetic Plain, Malabar, Deccan, Ceylon, Indus Plain, Maldives, Burma, Malay Peninsula, and Western Himalayas. The Western Ghats plunge under the Malabar botanical region of Hooker, which consists of the hilly or mountainous country's humid belt, continuing along the Western Peninsula.

The Western Ghats is a UNESCO World Patrimony and is one of the eight "hottest hotspots" for biological diversity in the world (Myers *et al*., 2000). According to Mani (1974), the Western Ghats are older than the Himalaya Mountains, as many hills on the Indian peninsula developed during the Archaean and Precambrian periods. The Western Ghats' mountain chain serves as the geomorphic appearance of tremendous significance characterized by distinguishing biophysical and ecological processes. The high montane forest ecosystems of the spot result from the Indian monsoon weather model. Abating the local tropical climate, presenting one of the leading examples of the earth's monsoon system (Gadgil, 1996), and displaying a significant number of biological diversity and endemism. It is considered one of the world's eight "hotspots" of biological diversity (Pascal and Ramesh, 1987). The Western Ghats are thought to be home to approximately 4000 species of flowering plants (Nayar, 1997), out of which about 1500 are endemic to the region (Chatterjee, 1939). The region's forests are some of the best examples of non-equatorial evergreen tropical forests, and it is home to at least 325 species of globally endangered flora, fauna, birds, amphibians, reptiles, and fish (Mittermeier *et al.,* 2011). Moreover, the southern Western Ghats is considered the richest in terms of floral diversity and endemism, constituting about 3900 species out of the 4000 species found in the Western Ghats in an area of about 12000 km^2 distributed over the southern parts of the states of Kerala, Tamil Nadu and Karnataka (Nayar, 1996b).

The science of phytosociology is concerned with the structure and development of plant communities, as well as the relationships between the species that inhabit them (Bhatt *et al*., 2014). A phytosociological system is a classification system for these communities. The aim of phytosociology is to develop an empirical coefficient model of vegetation by combining plant taxa that characterize vegetation units. It is useful in describing the population dynamics of each plant species in a specific community and how they are related to other species in the same community (Mishra *et al.,* 2012).

Phytosociological studies are essential for analyzing and understanding the structure, function, and forest dynamics. Phytosociology studies are useful for analyzing and understanding forest ecosystems' structural, dynamic, and functional attributes. Phytosociological studies also support appropriate management and sustainable utilization of forest resources. The plant community is described by its dominance, growth, species diversity, forms, and structure (Sharma, 1998). The phytosociological and floristic studies of Shendurney Wildlife Sanctuary will bridge the gap in understanding floristic richness, structure, community composition, and the relationship between the species and vegetation and soil, which are paramount to the management of the Sanctuary.

Biological diversity depends solely on numerous attributes, such as edaphic. Soil characteristics determine the type and productivity of an ecosystem. This study is aimed at studying the vegetation composition and the physicochemical properties of the soils in the major forest ecosystems. A comprehensive database on plant diversity, composition, the richness of its biodiversity, and soil physicochemical characteristics is a prerequisite for a better understanding of these ecosystems. It provides preliminary knowledge of these biodiversity hotspots and aid in the decision-making process for effective management and conservation approaches.

The science and technology of remote sensing and GIS have become unavoidable in biodiversity and natural resource management and conservation. The knowledge helps provide the basic concept of a monitoring system that eases generating data essential for the continuity of biodiversity conservation (Menon and Sasidharan, 2005). Vegetation mapping and classification is an essentially technical task for managing natural resources. The concept of vegetation mapping is currently based on ternary approaches, the application of remote sensing and geographic information systems (GIS), a multi-scale approach that includes landscape ecology, and a phytosociological basis (Bredenkamp *et al*., 1998). The application of remote sensing and geographic information systems are recognized as necessary for this investigation. Therefore, this study mapped the major forest ecosystems in order to gain a better understanding of land-use changes and vulnerability to habitat destruction, degradation, and loss.

The Shendurney Wildlife Sanctuary, situated in Thenmala, Kerala state, is a protected area that is a portion of the biosphere reserve of Agasthyamalai, recognized among the well-heeled regions of Western Ghats biodiversity. It was part of the erstwhile Travancore state. Accordingly, the forest of this sanctuary has been reasonably well-explored by exceptional forest botanists such as Bodeme R.H, Barber C.A., Bourdillon T.F, and Fischer C.E.C. during the late nineteenth and early twentieth centuries (Burkil, 1965). The Sanctuary may be one of the fully protected excellent models of evergreen forest within the Western Ghats and accommodates compelling populations of locally endemic species like *Gluta travancorica*. The Sanctuary is noticed as exclusive considering the existence of distinct and specialized habitats of yristica swamps, the moving terrain, rocky mountains, waterfalls, grasslands, in addition to the variety of forest types, etc., constituting a large variety of flora and fauna. The present study invariably documents the floristic richness and phytosociology by carrying out a vegetation analysis in the major forest ecosystems.

Despite the tremendous complexity of floral and faunal diversity in this sanctuary and unique forest ecosystems such as myristica swamps, no comprehensive investigation has been documented. The study entitled "Phytosociological and edaphic attributes of forest ecosystems of Shendurney Wildlife Sanctuary, Kerala," aimed to investigate the floristic diversity, structure, and soil physicochemical properties of major ecosystems in the Sanctuary and also to map the vegetation using a geographic information system (GIS).

The research work was planned with the following specific objectives:

- To study the phytosociology of forest ecosystems of Shendurney wildlife sanctuary
- To study various edaphic attributes of the forest ecosystems of Shendurney wildlife sanctuary

- To use the geographic information system to map the different forest ecosystems, as well as investigate changes in land use and land cover of Shendurney wildlife sanctuary

Review of literature

REVIEW OF LITERATURE

A forest is a complex ecosystem consisting of fauna and flora existing together and interacting with the components of their environment and supporting human life on earth. The role of forest ecosystems can not be exaggerated; the forest remains a vital and integral component of human sustenance. Forest ecosystems have proven to be exceptionally significant globally; they act as a rich reservoir for biological and genetic diversity. The components of forest ecosystems, such as soil, vegetation, micro, and macro-organisms, interact and provide essential ecosystem services such as purified water and air, climate regulation, nutrient cycling, carbon storage and sequestration, socio-economic, cultural and religious, and environmental stability, as well as providing the raw materials for food, fuel, and shelter. The forest plays an indispensable role in the conservation, enhancement, sustenance of the environment, maintaining ecological integrity, and providing a habitat for wildlife. The forest ecosystem is a dynamic and complex entity at every level of its development. Understanding basic forest ecosystem structure is essential to defining various ecological processes and figuring out the functioning and undergoing changes in the forest ecosystem (Elouard *et al.,* 1997). In these circumstances, the critical literature worthy of floristic, plant diversity, and phytosociological studies is presented below.

The literature review revealed that large numbers of plant diversity and phytosociological studies have been carried out worldwide. Since the work done on this aspect in India is very meager and scattered, the review has been strengthened by incorporating the related aspects.

2.1. PLANT DIVERSITY

India is home to a wide range of forest types. Based on physiognomy and climate, Champion and Seth (1968) classified Indian forests into five broad groups. They are further classified into 16 categories and 221 forest types, each complementing biodiversity. Approximately 66% of Indian forests are tropical moist to dry deciduous, 8% are tropical wet evergreen, 4% are tropical semi-evergreen, 9.5 percent are subtropical, 7% are temperate, and 5.8 percent are miscellaneous (Lal, 1989).

The country has been classified into biogeographical zones according to its biota and environmental realms (Rodgers and Panwar, 1988). India has almost all of South Asia's distinctive global ecological zones. These are; (i) tropical rainforest; (ii) tropical moist deciduous forest; (iii) tropical dry forest; (iv) tropical shrubland; (v) tropical desert; (vii) tropical mountains; and (viii) temperate mountains (FAO, 2001). The forest plays a vital role in biodiversity conservation, maintenance, improvement of ecological integrity, and providing a stable habitat for wildlife. Forest ecosystems are considered complex entities consisting of various living organisms that extend vertically upward into the atmospheric layer, wrapping forest canopies and downward to the soil surface influenced by roots and biological processes (Waring and Schlesinger, 1985). Forest ecosystem diversity studies document vital information on the various degrees of transformation within the forest and provide information that simplifies the management decision process.

2.1.1. GLOBAL REVIEW ON PLANT DIVERSITY

The plant community plays an enormous role in sustainable development through biodiversity conservation and environmental protection (Farooquee and Saxena, 1996). The wide range of ecological conditions, which are mostly determined by topography, has resulted in habitats that are suitable to the development of a diverse range of flora and fauna (Hobbs *et al.,* 1995). An analysis of vegetation based on a plot method is used to characterize the community, describe its floristic composition, and identify economically beneficial species and species of particular conservation concern (Keel *et al.,* 1993). Quantitative analysis of vegetation areas is an important indicator and tool for ecological studies (Hong *et al*., 2016).

Floristic composition is considered the quantum of floral diversity of any given community and one of the community's primary unique attributes (Prance, 1977). The floristic structure replicates the general climatic and edaphic peculiarities of the region. Vegetation in tropical forests has been extensively explored in several studies and investigations. The tree's size, i.e., diameter or girth at breast height (GBH/DBH; at 1.37 or 1.3 m), has been adopted for the computation. Several floristic diversity studies have reported the listing of individual trees as small as 2.5 cm dbh (Knight, 1975), 4.5 cm dbh (Bunyavejchewin, 1999), 5 cm dbh (Valencia *et al*., 1994; Johnston and Gillman, 1995), 10 cm dbh (Sahu *et al.,* 2007; Bhatt and Bhatt, 2016; Myo *et al*., 2016), 30 cm dbh (Devi and Yadava, 2006; Dhaulkhandi *et al*., 2008; Sharma and Samant, 2013; Sarkar and Devi, 2014), 91 cm dbh (Ho *et al.,* 1987) 152.4 cm dbh was also reported (Fox, 1967).

Wardell and Williams (1996) documented 857 vascular plant taxa in 441 quadrats of the Tingle Mosaic, South-Western Australia. These included 825 native and 32 introduced taxa. Papilionaceae (74 species), Proteaceae (73), Myrtaceae (64), and Orchidaceae (63) are among the most important families. Popma *et al.* (1988) established one-hectare plots in Mexico and documented 292 tree species. Steege *et al.* (2000) studied the diversity and floristic composition of the Amazonian forest, and reported that area and disturbance regime are the essential factors responsible for the differences in Alpha diversity between the eastern and western Amazonia. Bhatt and Bhatt (2016) conducted a similar study in central Nepal's temperate forest, and found a total of 31 individuals of 20 woody species, 18 genera, and 18 families in a 0.16 ha plot of natural forest.

The study of the plant communities' structure and composition is vital in forest conservation and management. Fonge *et al.* (2005) assessed the vegetation status of an 80-year-old lava flow of Mt. Cameroon, West Africa, and reported that 102 species were recorded, including 21 tree species, 13 shrubs, 20 herbs, and seven climbers. In the mixed deciduous and deciduous dipterocarp forest of the Minbyan Reserve Forest of Myanmar, the pattern of woody regeneration in terms of species composition and diversity has been investigated (Myo *et al*., 2016), and a total of 57 species of mixed deciduous forest plants belonging to 28 families and 342 individuals and 25 species of deciduous dipterocarp forest consisting of 15 families and 285 individuals have been reported. Higher diversity was observed in the mixed deciduous forest (H' = 3.68) compared to the deciduous dipterocarp forest (H' = 2.39). In Rober-Kerman, Iran, the patterns of plant associations were correlated with environmental factors by experimenting on the phytosociology of the associations between vegetation and environmental factors (Nosrati *et al.,* 2017). They identified 34 species; the species number per releve varied from 23 to 29 with an average of 25.2. Analyzing species diversity among the releves using diversity indices of Simpson, Shannon-H, Menhinick, and Margalef showed three relevés with 23 species. Only one out of 8 relevés with 24 species had the minor species diversity.

Adekunle *et al*. (2016) assessed the diversity and abundance of tree species of a strict Nigerian nature reserve. The study enumerated 387 stems ha^{1}, belonging to 94 tropical hardwood species, 80 genera, and 30 families. The dominant species and families were *Celtis zenkeri* of the Ulmaceae family and Sterculiaceae. The Shannon-Wiener index (3.75) and evenness (0.82), as well as other diversity indices, were both considerably high, indicating that the forest could be a biodiversity hotspot.

Hailu (2017) investigated the phytodiversity, herb biomass distribution, and physicochemical parameters of the Harishin Rangelands vegetation in Eastern Ethiopia, documented 58 herbaceous and 11 woody species in the research area. The analysis of the important value index for two management approaches was represented by several combinations of species with varied dominance. An overview of species distribution patterns revealed contiguous growth and a clustered distribution pattern for the majority of species strata. Grazing management approaches were distinguished by their species variety, richness, herb biomass, basal cover, and soil physicochemical properties.

2.1.2. INDIAN REVIEW ON PLANT DIVERSITY

Floristic inventory and diversity evaluations are critical to understanding current state of diversity and forest biodiversity conservation (Jayakumar *et* *al.,* 2011). The need for intensive floristic studies of different geographical regions is increasingly inevitable for proper documentation, conservation plans, as well as the sustainable utilization of plant resources. Reddy *et al*. (2008b) worked on the tree diversity of the tropical dry deciduous of Nallamalais, Andhra Pradesh. The study found 1541 angiosperm taxa, which fall into 778 genera and 144 families, bringing out the genus species ratio of 1:2. Poaceae (178 taxa) were dominant families: Papilionaceae (116), Euphorbiaceae (83), Cyperaceae (79), and Asteraceae (63). The spectrum of life forms was dominated by therophytes (37.1%), indicating a typical arid tropical climate. Similar studies were conducted (Reddy *et al*., 2008a), which established three 1 ha plots and reported a total of 137 tree species, 2205 stems (735 ha^{1}) of ≥ 10 cm in circumference were enumerated. Tree communities differ in composition, dominance, diversity, and structure. The density of the stand varied between 674 and 796 ha^{1}, with an average basal area of 11.46 m^{2} ha^{1}. The Shannon-Wiener index (H) varies between 4.11 and 4.9.

Rajendran *et al*. (2014) reported 335 vascular plant species represented by 222 genera belonging to 67 different families in the Bharathiar University campus biodiversity. The dominating families in the vascular floristic composition of the research region were the Poaceae, Fabaceae, Mimosaceae, Caesalpiniaceae, and Amaranthaceae. Nayar (1996b) has identified three hotspots of endemic centers in Kerala, viz. Agasthyamala has 189 endemics species, 94 species for Anamalai high range, and Silent Valley in Palakkad district.

According to Nayar (1977), India's wet evergreen forest, which covers 51249 km^{2} (about 1.5 percent of the country's geographical area), has approximately 7,000 species of flowering plants, accounting for slightly less than half of the Indian angiosperm flora. The vast diversity of tropical forests can be further appreciated because the 90 km^{2} area of Silent Valley in the Western Ghats is a home to 966 flowering plant species belonging to 559 genera and 134 families (Manilal, 1988). There is also a small region of local endemism in the Eastern Ghats (Mackinnon and Mackinnon, 1986).

Srinivas and Parthasanthy (2000) compared the diversity and dispersion in the upper and lower altitudes by establishing three one-hectare plots of tropical lowland evergreen forest in the Aagumbe central-western Ghats. They recorded 3202 live stems representing 125 species in 92 genera and 42 families. Richness was higher in the lowermost plot and lowest in the upper plot. The study observed a progressive decrease in the richness with increasing altitude. Devi and Yadava (2006) identified 123 species from 48 families in Manipur's semi-evergreen forest. Bhatt and Kaveriappa (2009) conducted an ecological study of the Myristica swamp forests of Uttara Kannada, Karnataka, using transect methods and depicting sixty-three species, including one unidentified species of tree and bamboo belonging to twenty-six families. *Myristica fatua*, *Gymnacranthera farquhariana*, and *Hopea ponga* dominate the forest. Reddy *et al.* (2006) described the vegetation and floristic diversity of the Bhitarkanika National Park, Orissa, containing approximately 372 species belonging to 262 genera belonging to 100 families, 370 species belonging to angiosperms, and two species belonging to Pteridophytes.

Diversity, richness, basal area, population structure, and tree species distribution patterns were studied in disturbed, moderately disturbed, and undisturbed Piranmalai, the Eastern Ghats, Tamil Nadu, tropical dry deciduous forest areas using the disturbance index (Pitchairamu *et al.,* 2008). Six 0.1ha sites have been established in the Piranmalai forest. The wealth of tree species varied in different stands along the gradient of disturbance. The highest species richness was demonstrated by the undisturbed stand (11-9). The species richness was lowest (5-4), while diversity was relatively greater in the moderately disturbed stand (8-7). The Shannon–Wiener tree species index ranged from 1.33 to 2.184 in all the stands. Kanade *et al.* (2008) established ten belt transects of 1000m × 5m size and enumerated all the individuals with GBH ≥15. They reported 4200 stems representing 107 species belonging to 86 genera and 44 families. The Shannon's diversity index value varied from 2.0 to 3.2.

Kandi *et al.* (2011) conducted an intensive study and evaluated the floristic diversity of Sunabeda Wildlife Sanctuary, Odisha, and found a total of 188 angiosperms and two gymnosperms belonging to 157 genera and 59 families, 154 dicotyledon species (128 genera and 52 families), 34 monocotyledon species (27 genera and five families), and two gymnosperm species (2 genera and two families). The study added to the prior knowledge of the floristic composition and phytodiversity of the area, which was crucial to the decision-making process for the optimal conservation and management of the sanctuary.

Bhuyan *et al.* (2003) assessed population structure and tree diversity in undisturbed and human-impacted tropical evergreen forest stands in Arunachal Pradesh, Eastern Himalayas, and asserted that the diversity of tree species differed along the gradient of disturbance in different stands, with a mildly disturbed stand showing the highest species richness (54 of 51 genera). The lowest richness (16 species of 16 genera) was reported in the highly disturbed stand, 47 species of 42 genera in the undisturbed stand, and 42 species of 36 genera in moderately disturbed stands.

Kushwaha and Nandy (2012) analyzed the richness and diversity of plants in the moist sal forests of northern West Bengal. They recorded 134 trees, 113 shrubs, and 230 herb species. Kanade *et al.* (2008) detailed the diversity of woody plant species in Chandoli National Park, an under-explored area in the northern Western Ghats, Maharashtra. They documented a total of 4200 stems represented by 107 species from 86 genera and 44 families. The Shannon's index value ranged from 2.0 to 3.2. The study discovered a new subtype, *Memecylon–Syzygium–Olea*, previously known as *Memecylon–Syzygium–Actinodaphne* floristic series in the literature. Melastomataceae was reported as the most dominant family IVI (50.32).

Three stands of tropical wet evergreen forest around Namdapha National Park and Arunachal Pradesh were studied for species composition, diversity, and tree population structure. The study documented a total of 200 plant species belonging to 73 families (Nath *et al.,* 2005). Rasingam and Parathasarathy (2009) studied and reported 4252 trees ≥30 cm in circumference at breast height, covering 186 species in 125 genera, and 56 families out of 23 species (12.4%) endemic to the islands.

Muthuramkumar *et al.* (2006) compared the plant community structure in tropical rain forest fragments of the Western Ghats with a systematic sampling method. They found 312 species in 103 families, including 144 trees, 2250 lianas, and 6123 understory plants (108 species). Tree species density, stem density, and basal area were similarly higher in the three larger (> 100 ha) rainforest fragments, but they were adversely connected with disturbance ratings rather than area per se, according to the study. The density of Liana species, stem density, and basal area were higher in moderately disturbed fragments and lower in severely disturbed fragments compared to the three larger fragments. Understory species density was highest in the highly disturbed 18-hectare portion due to weedy invader species coexisting with rainforest vegetation.

Sagar and Singh (2005) established 3-ha permanent plots and distributed 1500 quadrats in five of India's Vindhyan dry tropical forest sites. They enumerated 65 species with 136,983 individuals, the number of the stems varied from 12 to 50 and 8063–65331 per three hectare. Sahu *et al.* (2007) published a study on the phytosociology of the dry deciduous forest of Boudh District of Orissa. The research documented 187 species (91 trees, ten shrubs, 12 climbers, and 74 herbs) within the 4-ha sampled area. Stand density and species richness of tree species significantly decrease with increasing girth. Rao *et al.* (2014) documented 165 tree species from 119 taxa and 50 families, with 160 comprising dicots and 5 were monocots from the tropical forests of Vizianagaram in the Eastern Ghats region.

Triphati and Singh (2009) investigated the species diversity, structure, and concentration of dominance of woody plants in natural and planted forests. They discovered that tree densities in plantations were considerably higher than in natural forests. The riverine forest's basal area ranged from 24.84 m^2 ha^1 to 45.55 m^2 ha^1 in sal mixed forest. Riverine forests had the highest species richness (4.31) and sal plantations had the lowest (1.31).

Plants in 19 montane evergreen forests of the tropical montane evergreen forest (shola) of the Nilgiri Mountains were studied by Mohandas and Davidar (2009). They recorded a higher diversity of 30495 individuals from 87 species, 65 genera, 42 families, and 57 species: trees, 13 lianas, 12 shrubs, and five large herbs. Species diversity measured by Fisher's alpha was 11; stem density was 2652 stems ha1 and basal area was 59.4 m^2 ha^1. Krishnamurthy *et al.* (2010) established 2 ha (200 × 100) permanent plots, enumerated the tree diversity species in the tropical dry deciduous of Badhra wildlife sanctuary, and recorded 1766 individuals, 46 species, 37 genera, and 24 families were reported. Combretaceae was reported as the most abundant family in the forest, with an important family value of 68.3.

Sharma *et al.* (2009) examined the impact of altitude on the diversity, richness, and dispersion behavior of different tree species in the Himalayan temperate forest. They discovered that all growth indices, including Margalef's (0.17 to 1.14), Menheink's (0.27 to 0.80), species diversity (0.99 to 2.34), and Simpson's Diversity Index (1.49 to 8.73), were highest at lower altitudes (2250-1850 m asl), medium at mid-altitudes (2600-2400 m asl), and lowest at higher altitudes (2600-2400 m asl) (2800-2700m asl).

Sinha and Sinha (2013) undertook a diversity analysis of the vegetation of Baikunthpur, dist-Koria, Chhattisgarh, India, and enumerated phytosociological analysis of 140 medicinal plants and reported 100% frequency for *Alangium lamarckii, Lawsonia inermis, Diospyros melanoxylon, Shorea robusta*, and *Vicia* sativa. The minimum frequency of 10% was exhibited by *Croton tiglium*, *Curculigo* orchioides, *Grewia tiliifolia*, and *Lasiosiphon eriocephalus*. They observed that the study area is affluent with plant diversity, including medicinal plants, indicating a large tribal population using a wide variety of plants for their basic needs, livelihoods, and livelihoods in the study area.

Sharma *et al.* (2014) assessed vegetation structure and trend along the valley's altitudinal gradient in the Sangla Valley, Northwest Himalaya. They identified 320 species belonging to 199 genera and 75 families, with the dominant species belonging to Asteraceae, Rosaceae, Apiaceae, and Ranunculaceae. The maximum altitudinal distribution of a few selected climate-sensitive species was highest in the northeast and north.

Sarkar and Devi (2014) assessed tree species' diversity, population structure, and status in the tropical semi-evergreen forest. The study recorded a total of 75 tree species belonging to 60 genera and 40 families. They also noticed that tree species' overall population structure showed a reverse J-shaped population structure and potential regeneration status. The family Moraceae was dominant, having eight different species, Magnoliaceae with five difference species, Anacardiaceae, Euphorbiaceae, Lauraceae, and Meliaceae, recorded four species each respectively. This research provides in a deeper knowledge of the diversity of tree species found on the study site.

2.1.3. KERALA REVIEW ON PLANT DIVERSITY

Kerala's unique diversity of species and vegetation is attributed to a warm, humid climate, perennial water resources, and soil rich in nutrients. The state is bestowed with distinctive forest ecosystems, predominantly: tropical wet evergreen, tropical moist deciduous, tropical semi-evergreen, dry deciduous, and Shola-grassland forest (Champion and Seth, 1968). The state has been endowed with patches of mangroves along the coastal line (Anupama and Sivadasan, 2004), and myristica swamps, an extraordinary and distinguished type of evergreen vegetation in the Achenkoil and Kulathupuzha valleys of the Kollam district and the adjacent Kottur district of Thiruvananthapuram (Mohanan and Daniel, 2005).

Then Hooker (1907) observed that the unique features of the 'Malabar flora' primarily belong to the families Arecaceae, Anacardiaceae, Bambusaceae, Clusiaceae, Dipterocarpaceae, Myristicaceae, Araceae, Gesneriaceae, Myrtaceae, Melastomaceae, Meliaceae, Orchidaceae, Piperaceae, Tiliaceae, and Zingiberaceae. According to Nayar (1996), there are approximately 3800 species of flowering plants in Kerala, of which 1272 are Western Ghats endemics. Sasidharan (2004) emphasized that there are 1381 endemic taxa in Kerala, of which 496 are placed in threat categories. Giriraj *et al.* (2008) established a three-hectare plot in Kalakad-Mundanthurai tropical wet evergreen forest with an altitudinal range of 1170 to 1306 m. They enumerated 5624 individuals, 68 woody species belonging to 52 genera and 27 families.

The structure and composition of tropical evergreen and deciduous forests in the Western Ghats were studied by Murthy *et al.* (2016). Six one hectare permanent plots were established as representative of each evergreen and deciduous forest zone. Within each permanent plot, woody plants with a diameter of more than 10 cm DBH (Diameter at Breast Height) have been identified, including tree saplings, lianas, climbers, etc. For more disturbed evergreen plots, the total number of 106 and 54 species of trees were recorded; there was a greater diversity of species in second and the third of the more disturbed plots (106 and 68) compared to the less disturbed plots. The study found that the evergreen, more disturbed' and deciduous plots have fewer species than the less-disturbed forests. In all locations, there are also differences in the size of the class structure in more and less disturbed forests. Variations are especially obvious in the DBH size class, which ranges from 10-15 cm.

Varghese and Balasubramanyan (1999) worked on the diversity, structure, and composition of the Agasthyamalai region's tropical wet evergreen forest and documented 435 individuals stems belonging to 79 difference species and distributed among 37 families. Medium diversity (index value of Shannon 3.143), high species richness (index value of Margalef 7.07), and low species evenness (index value of Pielou 0.89) were recorded.

The wet temperate montane forest is distinct in its diversity and its prominent appearance in phenology. In the Palni Hills, Kukkal Forest southern Western Ghats, Sellamuthu and Lalitha (2010) monitored the trees' phenological pattern and diversity in a mountainous wet temperate forest (shola) by establishing 12 randomly selected plots for vegetation sampling. Twenty-three fleshy fruit trees were also established for phenological studies in the reasearch area. Ten individuals from each species were chosen to record phenological occurrences every two weeks. They documented 2279 individuals belonging to 83 different species, 68 genera, and 40 families, with approximetely 30% of the species being indegenous to the Western Ghats region. *Psychotria nilgiriensis* var. astephana (Rubiaceae) was the most dominant species, accounting for 12 percent of the sampled individuals.

Lauraceae was the dominant family, representing 20 percent of the population. The study reported that the number of fruiting showed no association between species and rainfall (r = 0.26, p = 0.2), although there was a correlation between fruit abundance (r = 0.40, p >0.05).

Haritha and Nandu (2016) investigated three sacred groves' floristic attributes in Kannur, North Kerala. Phytosociological and floral diversity of the three sacred groves were compared, and biodiversity indices were used to detail the vegetation characteristics. The study documented a sum of 107 species constituted of trees, shrubs, and herbs. Nonvascular plants, gymnosperms, and lianas were primarily observed in these groves. A more significant number of endemic threatened individuals were also reported from all three of the groves.

Deepa *et al.* (2017) plant diversity and structural characteristics were investigated in Chithalikavu, a sacred grove in Thrissur district, Kerala. The floristic composition revealed the occurrence of 57 angiosperm species belonging to 54 genera and 35 families; 29.82 percent are trees, 24.56 percent are shrubs, 15.79 percent are herbs, and 29.83 percent are climbers. As it constitutes the highest IVI, *Strychnos nux-vomica* was identified as the community's most dominant species.

2.2. PHYTOSOCIOLOGY

Phytosociological research have a particular interest in tropical forests due to the great range of patterns and processes associated with their diversity .The study of phytosociology focuses on the composition of plant communities, evolution, and the existing associations between the component species and the classification, including species diversity, growth, and succession trends (Muller–Dombois and Ellengberg, 1974).

2.2.1. GLOBAL STATUS ON PHYTOSOCIOLOGY

The plant community's study concerned with their components, structure, and classification that comprehends species diversity, growth, the direction of succession, etc., is termed phytosociology (Muller-Dombois and Ellengberg, 1974).

Tropical forests have risen in importance in recent decades due to both their natural and social and economic characteristics, resulting in scientific, ecological, and social debates (Lima *et al.,* 2012). Moreover, there are just a few studies on these ecosystems' floristic, structural, and dynamic composition. The science of phytosociology deals with plant communities, their composition, evolution, and the existing relationships between the component species. Plant communities are groups of plant species that form a relatively homogeneous patch that can be distinguished from nearby patches of different vegetation types within a defined geographical area (Pott, 2011).

Phytosociology is a branch of science that studies plant communities, their composition and development, as well as the interactions between species within them. From the early decades of the 19th century, phytosociologists tried to standardize the sampling and study vegetation characteristics (Braun-Blanquet, 1928) and use a formal framework for naming and organizing within a hierarchy of orders, associations, and classes (Barkman *et al.,* 1986).

Beeck (1972) studied the phytosociology of the Northern Conifer hardwood forests of the central St. Lawrence Lowlands of Quebec and Ontario. The investigation presented a qualitative and detailed quantitative description of the ecological relationships of 54 trees and 516 herbs and shrubs in a wide variety of forest communities. Foster (1984) studied the phytosociological characteristics of forest vegetation in Labrador. He described 77 plant species and grouped them into five assemblages: birch, fir-spruce-feather moss, *spruce-fir*, *spruce-pleurozium*, and *spruce-sphagnum fuscum* communities.

Jarman *et al.* (1991) worked on floristic and ecological studies in the Tasmanian rainforest and reported four major floristic groups. These were grouped into two alliances, the *Nothofagus cunninghamii* and the *Athrotaxis cupressoides*. Damm (2001), in a phytosociological study of Glacier National Park, Montana, U.S.A, reported three classes, six orders, 32 associations, 26 sub-associations, and seven other communities. Lepping and Daniel (2007), on the phytosociology of beach and salt marsh vegetation in Northern West Greenland, reported a new vegetation type, i.e., *Cochlearia groenlandica-Melandrum triflorum.*

Peinado *et al.* (2011) studied phytosociology and characterized the Pacific Northwest, North America dune forests and reported four different associations: *Pseudotsugo menziesii-Pinetum contortae, Arctostaphylo uva-ursi-Pinetum contortae, Carici obnuptae-Pinetum contortae, Morello californicae-Pinetum sitchensis, and Pseudotsugo menziesii-Pinetum contortae*. Silva *et al.* (2016) characterized the vegetation structure with naturally occurring manga in Recanto, Patizal, and Recurso, villages in Brazil. The study reported 2,112 live individuals, 1,056 individuals belonging to 33 species and 20 families from the regenerating stratum, and 1,056 from 22 species. The regenerative stratum has greater floral diversity than the adult stratum. *Hancornia speciose* achieved a relevant position in all computed parameters in the three sampled villages, with importance values ranging from 25.15 to 29.38 percent for the regenerating and 29 to 56.64 percent for the mature stratum, showing the species' relative ecological significance.

2.2.2. STATUS ON PHYTOSOCIOLOGY IN INDIA

British experts have initiated floristic and phytosociological studies in India. Notable prominent people contributed to the floristic studies in India (Roxburgh, 1820-1824; Wight and Arnott, 1834; Beddome, 1869-1874; Hooker, 1872-1897; Cooke, 1901-1908; Gamble and Fischer, 1915-1936). Wight authored 28 works, the most noteworthy of which are Illustrations of Indian Botany (1840-50) and Icones Plantarum Indiae Orientalis (1838-1853). Wight and Arnott (1834) published the Prodromus Florae Peninsulae Indiae Orientalis. Beddome (1869-1874) detailed The Flora Sylvatica for Southern India, Ico nes Plantarum Indiae Orientalis (1868-1874), and Flora Indica by Roxburgh (1820- 1824). Hooker published the Flora of British India from 1872-1897. Regional floras were published, including Flora of the Presidency of Bombay (Cooke, 1901-1908) and Flora of the Presidency of Madras (Gamble and Fischer, 1915-1936). During that time, more studies were published from India's southern peninsula, the flowering plants of Travancore (Rama, 1914), the Flora of Anamalai Hills, Coimbatore

District (Fischer, 1921), and the Flora of South Indian Hill Stations (Fyson, 1932), the flora of Tamil Nadu, India (Nair and Henry, 1983; Henry *et al*., 1987 and 1989) and the flora of Karnataka (Sharma, 1984). The Flora of Tamil Nadu-Carnatic (Matthew, 1983) was one of the most notable publications.

The phytosociological study of Navegaon National Park in Maharashtra was carried out by Ilorkar and Khatri (2003). In the moist deciduous forest of Navegaon, the study recorded 40 tree species, 16 shrub species, and 44 plant species. This is lower in comparison to the evergreen forests. Arunachalam (2002) recorded only 18 tree species, seven shrub species, and 10 species of herbs in the dry deciduous forest of the Thaniparai reserve in Tamil Nadu. Similarly, the floristic composition of tropical dry deciduous forests is poor since the prevailing conditions support only fewer species, likewise the tropical dry deciduous forests in the Badrama reserve of Odisha (Devi and Behera, 2003). Hence, it indicates that the tropical evergreen forest ecosystems alone support a rich floristic composition regarding species and diversity. Phytosociological observations on the diversity of tree species in the Andaman Islands were carried out (Padalia *et al.,* 2004). The study documented 369 tree species from 233 genera and 77 families. Among the families recorded, Euphorbiaceae is the dominant one.

Ecological research on Myristica swamp forests in Karnataka's Uttara Kannada district concerning floristic composition, structure, and diversity were studied (Bhat and Kaveriappa, 2009). Sixty-three species, including one unknown species of tree and bamboo, belonging to 26 families were recorded. The swamp is dominated by *Myristica fatua*, *Gymnacranthera farquhariana*, *Hopea ponga*, and *Dipterocarpus indicus*. With a maximum Importance Value Index of 102.63, the Myristicaceae dominated the swamps, represented primarily by *Gymnacranthera farquhariana* (57.83) and *Myristica. fatua* (38.49).

Bijalwan *et al.* (2009) conducted a phytosociological study of the Balamdi watershed of Chhattisgarh plains. They observed that in the overstorey strata, the trees were comparatively more magnificent than in the understorey, and the number of tree species varied from 12 to 21 species with a total number of 553 to 842 trees per hectare in the overstorey and 9 to 17 species with a total of 203 to 415 seedlings per hectare in the understorey. Arvind *et al.* (2010) characterize the phytosociological analysis in the Balamdi watershed of mixed dry tropical forest in the Chattisgarh plains. The study reported that the upper storey tree strata in the different aspects were comparatively more prominent than the understorey seedlings. The number of tree species ranges from 12 to 21 in the upperstorey to 9 to 17 in the understorey.

A study conducted by Kumar and Desai, (2016a) on plant biodiversity and phytosociological investigation in the Chikhali Taluka, Navsari district. A total of 72 species representing 40 families and 67 genera were documented. Of 72 species, 36 are tree species, 34 are herbs, and two are orchids. The maximum IVI was recorded for *Tectona grandis* (76.385) and followed by *Adina cordifolia* (21.978), *Terminalia tomentosa* (19.682), *Syzygium cumini* (14.929) and *Oroxylum indicum* (13.293), respectively. The highest Shannon-Wiener index value among the herb species was recorded for *Commelina benghalensis*, *Curculigo orchioides*, *Phaseoluss pecies*, and *Sonchus oleraceus* (0.162) and followed by *Tridax procumbens* (0.124). The phytosociology of the Waghai forest range, South Gujarat was described by (Kumar and Desai, 2016b) and inventoried a total of 62 species representing 37 families and 54 genera. 34 trees (17 families and 27 genera), 24 herbs (20 families and 27 genera) and 4 orchids were classified from the total of 62 species. Fabaceae were reported as the most diverse family.

Bhatt *et al.* (2014) extensively assessed the annual changes in phytosociological aspects of *Picrorhiza kurroa* in the high altitudinal zone of the Kumaun Himalaya of Uttrakhand. The study aims to observe the annual distinction in relative values of density, frequency, abundance, and importance value index (IVI) of individual species seriously threatened and classified as gravely endangered. The phytosociological survey reported high floristic richness from the region.

Singh and Shukla (2017) carried out an ecological study of a few selected medicinal plants with particular objective on the phytosociological aspect in Anpara region. They observed that out of 15 selected medicinal plants, *Cynodon dactylon* has a maximum value of RF, RD, RM, IVI, followed by *Datura Stramonium, Vernonia cinerea,* and *Abrus precatorius.* They also reported that *Scoparia dulcis* has a minimum RF, RD, RM, and IVI value. Species composition and phytosociological of Chanderbadni Sacred forest in Garhwal Himalaya presented 80 species representing 75 genera from 40 families and reported 21, 27, and 32 for trees, shrubs, and herbs, respectively.

Kumar (2019) conducted a phytosociological analysis of the tropical deciduous forests of the Keshkal Valley. The phytosociological analysis was based on data gathered from randomly placed sample plots encompassing the entire valley area. The sampled quadrates contained a greater diversity of 401 species. The species present as per preponderance are trees, 221 of herbs, and shrubs 180. All the enumerated species showed maximum frequency, density, and abundance values in the rainy season compared to the summer and winter seasons. Sahu *et al.* (2007) conducted a phytosociological study of the tropical dry deciduous forest Within a four-hectare sampling area, 187 species were identified (trees 91, shrubs 10, climbers 12, and herbs 74).

2.3. ECOLOGICAL AND PHYTOSOCIOLOGICAL STUDIES IN KERALA

The wet, humid climate with abundant water and nutrient-rich soil has resulted in diverse vegetation with a large number of tree species in Kerala. Like that of the Western Ghats, its floristic diversity is of an ancient lineage (Arisdason and Lakshminarasimhan 2014). Such an ancient flora is not just a reservoir of botanical antiques, but a dynamic biological source where speciation occurs at an accelerated speed (Nair and Daniel 1986). Forests in the Western Ghats, like those elsewhere in India, are, on the one hand, protected under the Forest Conservation Act of 1980 from conversion , but they are nevertheless prone to human usage and disturbance. Champion and Seth (1968) divided Indian forests into five primary divisions and nearly 200 sub-categories. The Western Ghats region is predominated by the major groups of moist tropical forests, such as (1) wet evergreen forests characterized by densely distributed tall trees, sufficient lianas, climbing shrubs, epiphytes, and mosses; (2) semi-evergreen forest characterized by the abundance growth of mixed evergreen and deciduous trees and attributed to a dense undergrowth of ferns, herbs, and abundant grasses; (3) Moist deciduous forests, dominated by deciduous tree species and understorey shrubs; (4) Swamp and Littoral forest predominated by halophytic flora (Singh and Charturvedi, 2017).

Rai and Proctor (1986) conducted ecological studies on four rainforests at 575-800 m altitude. They found that the three forest sites are species-rich with an important contribution from the Dipterocarpaceae. Still, one site is unusual and has an almost non-specific dominance by *Poeciloneuron indicum* (Guttiferae). Krishnan and Davidar (1996) examined the understorey community in the wet evergreen forest. They concluded that the Western Ghats' evergreen forests contain the richest understorey plant community.

Over the last two decades, tropical forest studies on large-scale permanent plots have drawn attention from ecologists (Condit, 1995). Ayyappan and Parthasarathy (1999) established a permanent plot for long-term ecological study on biodiversity and forest functioning in the tropical evergreen forest at Indira Gandhi Wildlife Sanctuary and National Park in the Anamalais of the Western Ghats was established. The study enumerated all the trees $\geq$ 30 cm GBH were numbered and their girth measured. They reported 148 tree species belonging to 120 genera and 49 families from the total sample of 13,393 individuals. The patterns of species dispersion, diversity, density, were analysed. The Sorenson's similarity index for thirty 1-ha subplots varied from 0.7 to 0.9, demonstrating the stand's uniformity in species composition.

Sasidharan (1999) documented 951 species of flowering plants from 581 genera and 118 families in the Shenduruny Wildlife Sanctuary, Kerala. The study reported high degree of endemism of 310 species out of the 951 species. Srinivas and Parthasarathy (2000) determined the diversity, density, altitudinal variation, spatial pattern as well as the species composition of the tree species. The study observed a more significant number of families (34 and 33) in the lower altitudes and the least (23) in the uppermost plots. A substantial proportion of large trees and emergent species were contained in the lower altitude plots. Altitude and density were positively correlated, whereas species richness and basal area were negatively correlated.

Sasidharan (2002) also reported 1432 of angiosperms species classified into 753 genera and 140 families from the Parambikulam Wildlife Sanctuary, which account for approximately 35 percent of the Kerala's estimated flora. Dicotyledons are represented by 1119 species divided into 587 genera and 120 families, while monocotyledons are represented by 313 species divided into 166 genera and 20 families. Pascal and Pelissier (1996) set a permanent plot of 28 ha in a dense wet evergreen forest in India's Western Ghats and observed the ecosystem's functioning since 1990. The study recorded 635 individual trees species with 39.7 m^2 ha^{-1} basal area. Regardless of the high diversity (Simpson's D = 0.92 and Shannon's H '= 4.56), four species are distinct, dominant in terms of an importance value index, each occupying different layers in the ecosystem: *Humboldtia brunonis* (Fabaceae) dominates the undergrowth, *Myristica dactyloides* (Myristicaceae) the intermediate strata, *Vateria indica* (Dipterocarpaceae) the higher canopy level, and *Dipterocarpus indicus* (Dipterocarpaceae) the emergent.

The tree species diversity and distribution in undisturbed tropical wet evergreen forest of southern Western Ghats were studied (Parthasarathy, 1999). The composition, abundance, population structure, and distribution patterns of all woody species (30 cm GBH) were investigated. A total of 2150 stems (mean density of 716 ha^{-1}) were reported, representing 122 species in 89 genera and 41 families. Species richness was greatest (85 species ha^{-1}) in the undisturbed site, intermediate (83 species ha^{-1}) in selectively felled and lowest (80 species ha^{1}) in frequently disturbed. Tree density was greatest (855 stems ha^{1}) in selectively felled, intermediate (720 stems ha^{1}) in the undisturbed site and lowest (575 stems ha^{-1}) in frequently disturbed. The forest stand was exceptionally voluminous in the undisturbed site (basal area of 94.64 m^2 ha^{-1}), intermediate (66.9 m^2 ha^{-1}) in selectively felled and least (61.7 m^2 ha^{-1}) in frequently disturbed, due to the destruction of trees for fuel in the latter sites. The species composition and abundance trends differed significantly between the three locations.

Vijayan *et al.* (2015) investigated the floristic diversity and structural analysis of mangrove forests in Ayiramthengu, Kollam, and reported a total of 9 species belonging to 6 families. The forests exhibit the dominance of *Avicenna marina* and *Avicennia officinalis*, belonging to the Avicenniaceae family. The Shannon Weiner index H' (2.763), equitability (0.872), and Simpson's diversity index (0.825) were recorded. Rahees *et al.* (2014) conducted a phytosociological analysis of the mangrove forest at Kadalundi-Vallikunnu community reserve and enumerated a total of 7 species belonging to 5 families. *Avicennia officinalis*, *Rhizophora mucronata*, and *Excoecaria agallocha* were the dominant species recorded. The Shannon Weiner index (H') was 2.117, the Equitability index (e) was 0.745, and the Simpson's diversity index (D) was 0.713.

The plant diversity of an undisturbed forest was reported (Ganesh *et al.*, 1996); a total of 173 woody plant species belonging to 58 families were enumerated. Out of which, 50% were tree species. The Shannon-Weiner (H ') diversity index was the highest in the ranking (4.87) among similar Western Ghats sites. *Cullenia-Aglaia-Palaquium*, which is considered a subtype of *Cullenia-Mesua-Palaquium* was identified as the dominant species. Varghese and Balasubramanyan (1999) assessed the structure, composition, and diversity of the tropical wet evergreen of Agasthyamalai. They reported a total of 435 individuals belonging to 79 species, spread over 37 families. The study also discovered medium Shannon's index value of 3.14, high Margalef's index of species richness (7.07) and a relatively lower value of Pielou's index of species evenness (0.89), respectively.

Kumar *et al.* (2010 a) reported 93 tree species from 85 genera and 24 families from Western India's dry deciduous forest. The Shannon-Weiner Index (H') ranged from 0.67 to 0.79, the Simpson index of dominance ranged from 0.08-0.16 while the Margalef's index was found ranging from 21.41-23.71. The family

Combretaceae were represented by the highest number of species (9 species), followed by the Rutaceae (7 species).

Tropical dry deciduous forests were studied for their structure, diversity, and regeneration (Sagar and Singh, 2005). The study reported 65 different species with 136,983 individuals in 15 hectare area for all the stems ≥ 30 cm. The number of species and stems ranged from 12 to 50 and 8063 to 65331 per 3 hectare area. In a tropical dry deciduous forest, the vegetation composition was examined, and a total of 46 species and 4033 individuals (≥9.6cm dbh) were reported in a cumulative 15 ha permanent plot (Sagar and Singh, 2003). A similar study in the tropical semi-evergreen forest of the Kalyayan hills of the Eastern Ghats. The species richness, density, and population structure of all trees and lianas (≥30cm GBH) were inventoried. A total of 2064 items belonging to 74 genera and 39 families were recorded. The forest is dominated by *Nothopegia heyneana* and *Celtis philippensis*, which contribute 50% of the total density. The Shannon index varied from 2.31 to 2.87. The species richness and tree density decreased with girth as tree girths increased (Kadadul and Parthasaranthy, 1999).

Across various strata, the vegetation structure and diversity of species in natural and planted forests revealed that the understorey exhibited the highest richness and diversity of woody vegetation, with the lowest richness and diversity of climbers in natural and planted forest. Though the richness of the understorey level (saplings and seedlings) was higher in planted forests, the diversity value was lower (H=1.46) compared to the natural forest (H=2.05) (Tripathi and Singh, 2009). A human-dominated landscape in the Western Ghats of southern India investigated species diversity, community composition, and regeneration status of tropical forests. A total of 106 species of trees, 76 species of saplings, and 79 species of seedlings were reported. The forest ecosystem is dominated by abundant species such as *Albizia amara*, *Nothopegia racemosa*, and *Pleiospermum alatum* (Anitha *et al*., 2010).

Gautam *et al*. (2014) examined species recovery and change in community composition of the unmanaged moist deciduous forest of Northern India for four decades. Species richness and regeneration were studied in the context of the over-storey structure. Out of 130 species reported from these forests, only 68 species were recorded. The study observed changes in community composition, with *Mallotus philippensis* becoming dominant in one community. Dutta and Devi (2013) documented 89 plant species (34 trees, 15 shrubs, 25 herbs, and 15 climbers) belonging to 77 genera and 45 families in the tropical moist deciduous forest. The Shannon-Wiener diversity index varies from 2.02 to 2.43.

Naidu and Kumar (2016) compared the tree community characteristics of the tropical deciduous forest of the Eastern Ghats. A total of 2227 individuals were reported, representing 44 families, 98 genera, and 129 species. The most significant value index was found in the families Combretaceae, Euphorbiaceae, and Anacardiaceae. The Shannon-Weiner index (H') value ranged from 3.76 to 3.96, while the Simpson index raged from 0.96 to 0.97. The composition, population structure, and distribution of dipterocarps of the tropical evergreen forest of the Varagalair Western Ghats were investigated by (Ayyappan and Parthasarathy, 2001) using 30 hectare of permanent plots. The study observed that the three species of Dipterocarpaceae, viz. *Dipterocarpus indicus*, *Hopea parviflora,* and *Vateria indica*, contributed to 2% of tree species richness, 68% of stand density, and 18.3% of stand basal area.

2.4. POTENTIAL OF SPECIES REGENERATION

Under various environmental conditions, regeneration is a critical mechanism for the survival of organisms in a population. Following multiple disturbances, regeneration is an integral component of forest management because it preserves the desired species composition and stocking (Khumbongmayum *et al*., 2005). Thakur (2018) evaluated the floristic composition, structure, diversity, and biomass of understorey vegetation in the Achanakmaar Amarkantak Biosphere Reserve's dry tropical forest, documenting 2919 plant individuals from 66 species, 62 genera, and 31 families.

Armestto and Fuentes (1988) investigated the regeneration of canopy and sub-canopy in a mid-elevation primary rainforest in the coastal range of Isle de-Chile by comparing the seedling and sapling abundance under the forest canopy and within the 36-tree fall gap. They observed that the seedlings and saplings abundance revealed that the dominant species could regenerate below the canopy. However, they germinate and display enhanced growth within a limited light gap. The regeneration of native woody species in the plantation and neighbouring natural forest at Munessa-Shashemene was investigated (Senbeta *et al*., 2002). The study recorded 56 naturally regenerated woody species beneath all plantation stands, with densities ranging between 2300 and 18650 individuals per hectare in different stands.

Poorter *et al.* (1996) studied the regeneration of canopy tree species at five sites in the West African moist forest. The study recognized three major types of population structure: a decrease in the number of individuals with size, the typically inverse J-shaped curve indicating sufficient regeneration; an increase in the number of individuals with size, showing absent or sparse regeneration; and a variable consisting of strongly fluctuating patterns, in most cases, many small individuals, no intermediate ones, and many large ones.

Jaykumar and Nair (2013) worked on species diversity and tree regeneration patterns of different vegetation types in the Western Ghats, India. The study indicated that trees' diversity and regeneration patterns vary in different vegetation types of the forest landscape. The tree regeneration potential was more significant in species-rich vegetation with no human interruption. The variation in species composition across the mature and regenerating phases was more regular in the disturbed forest than in the less disturbed or undisturbed forests. Fredericksen (1999) concluded that tree species regeneration problems were most severe for shade-intolerant and intermediate shade-tolerant hardwood species in their review of important tropical forest tree species' regeneration status in Bolivia.

Mishra *et al.* (2013) examined the potential of tree species regeneration in a tropical moist deciduous forest. They recorded 74 plant species from 60 genera belonging to 32 families, of which 71 species are trees, 56 are seedlings, and 60 are saplings. *Mallotus philippensis*, *Tectona grandis*, *Shorea robusta*, *Syzygium cumini* and *Bombax ceiba* are the dominant species with higher importance value indexes. The study observed that about 19% of economically important plant species, like *Terminalia elliptica*, *Madhuca longifolia*, and *Buchanania cochinchinensis*, are found in poor regeneration categories, while almost 7% of species are found in no regeneration categories.

Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India, was assessed by Bhuyan *et al.* (2003). The study reported that out of the 47 tree species in the undisturbed stand, only 26 were found to be regenerating; thirteen species showed good regeneration, with the predominance of saplings and seedlings, which contributed more than 90% of the total density of a species. Eight species had fair regeneration, and five species showed poor regeneration. They concluded that seedlings and saplings of these emergent species are regenerating adequately in all the stands, despite competition from sub-canopy and herbaceous species. The data on tree species' regeneration status indicates that these species show the continuous establishment of seedlings and saplings because of their widespread occurrence in the forest. Rajesh *et al.* (1996) studied the regeneration characteristics of selection felled forest gaps of different ages in the evergreen forests of Sholayar, Kerala. They observed that younger gaps (up to 10 years of age) were characterized by higher litter turnover rates, which may have also favored soil organic C status.

Mahapatra *et al.* (2013) inventoried the plant diversity in the tropical deciduous forests of the Eastern Ghats. The diversity and density of herbs, shrubs, lianas, and tree species regeneration were assessed from 5 x 5 m plots within transects. The study reported 882 species belonging to 532 genera, and 129 families were recorded, comprising 263 tree species, 78 species of shrubs, 138 species of climbers, and 403 species of herbs.

Dhaulkhandi *et al.* (2008) studied the regeneration potential and community structure of a natural forest site in Gangotri, Uttarakhand. They recorded 73 species, and *Picea smithiana* was dominant, and *Cedrus deodara* was a co-dominant species. The highest density was recorded for *Pinus wallichiana* (1080 seedlings per hectare) followed by *Picea smithiana* (1040 seedlings per hectare) in the seedling stage. Regeneration status was concerned; 71.4% of species showed good regeneration.

2.5. EDAPHIC ATTRIBUTES OF FOREST ECOSYSTEMS

Plants' growth and development are intimately linked to soil characteristics. Plants respond to the dynamic of soil characteristics such as texture, moisture, and chemical properties like pH, CEC, etc. Over the decades, there has been an increasing concern about soil and vegetation studies globally. Scientific investigation into this subject has enabled a more proper understanding of various soil properties' effects on the forest ecosystem's growth, distribution, and composition. Characteristics such as pH, moisture, and nutrient recycling within the soils are integral features to ascertaining the site characteristics. Edaphic factors play a vital role in the plant colonization process. The type and number of plant species improve the soil's nutrient level. However, the plants are selective about the type and amount of nutrients utilized (Fonge *et al*., 2005). Soil attributes influence endemic trees and non-arborous vegetation (Abdo *et al*., 2017). Exchangeable sodium, organic matter, cation exchange capacity, exchangeable calcium, and sand content were the significant soil properties sustaining the forests' regenerative capacity and luxuriant characteristics (Eni *et al*., 2012). The increase in soil acidity with an increasing age gap could be attributed to the release of organic acids into the soil, often associated with a higher quantum of litterfall and faster litter turnover rates.

Soil controls the trees' structure, growth, composition, potential regeneration, vitality, and productivity (Bhatnagar, 1965). Soils' physical and chemical characteristics vary spatially and temporally due to deviations in climatic, topographic, weathering, vegetation, microbial activities, and several other biotic and abiotic factors. Vegetation also plays a more significant and crucial role in soil formation (Chapman and Reiss, 1999). The importance of nutrient factors in a plant community depends on their amounts and distribution (Saarsalmi *et al.,* 2001). Nutrient supplies vary widely among ecosystems (Binkly and Vitousek, 1989), resulting in differences in plant community structure and composition (Ruess and Innis, 1977). Many workers concluded that forest soils influence the composition of forest stands and ground cover, the rate of growth, and the vigor of natural productivity (Bhatnagar, 1965).

2.5.1. FOREST SOIL TYPES

The forest ecosystem's functions and values are definite and variable depending upon the numerous soil physical, chemical, and biological properties and processes that differ across spatial and temporal scales (Schoenholtz *et al*., 2000). The knowledge of soils' chemical and physical properties is paramount to foresters in assessing sites' capacity to support productive forests. Vegetation has an apparent effect on various soil properties (Banerjee *et al*., 1985; Miles, 1985). Soil and vegetation reciprocally interact; vegetation helps improve soil structure, soil moisture, and water holding capacity, infiltration rate, hydraulic conductivity, and soil aeration (Kumar *et al.,* 2004). Soils differ significantly in nature and composition with geological forms, aspects, and the extent of the slope, climate, and vegetation (Saxena and Srivastava, 1973).

Among various microenvironmental factors, soil nutrients affect plant growth and species' distributions within a forest (John *et al*., 2007). Soils within forests are not static but instead dynamic in space and time. Plant tissues of the aboveground litter and below-ground root detritus are the primary sources of soil organic matter (SOM), which influences physicochemical characteristics of soils such as pH, water-holding capacity (WHC), texture, and nutrient availability (Johnston, 1986). The significant increase in organic matter from woody debris results in the "fertilization" of the forest floor, adding to the elemental pools available for release by decomposers (Likens *et al*., 1978).

The ability of soil to stabilize soil organic matter depends negatively on altitude (Sheik *et al*., 2009) measured the stocks of SOC along an altitudinal gradient in coniferous subtropical and broadleaf temperate forests of the Garhwal Himalaya. The SOC stock decreased with altitude in both temperate (*Quercus leucotrichophora* and subtropical (*Pinus roxburghii*) forests. Dead standing trees in the forest play an equal role in C-stock storage as live trees. Gosain (2016) compared the soil physicochemical properties, dead standing trees biomass, and C-stock between 1261 to 2200m elevations in the Sitlakhet and Bimola forests, district Almora, Uttarakhand. He reported that all the soil physicochemical properties in Pine forests decreased with increasing depths, higher in the Bimola forest than in the Sitlakhet. The average total C-stock in Bimola dead standing tree pine forests was more than twice that of Sitlakhet Pine forests.

Zinke (1962) reported the patterns of influence of individual forest trees on soil properties in California's forested areas. He observed the exact pattern of surface soil properties on the trees. He assumed that the soil properties under the forest tree's influence would develop symmetrically around each tree in the absence of external variables like steep slopes or wind. Jina *et al*. (2001) analyzed the soil physicochemical parameters of different forest statuses (*P. roxburghii* Sarg. and *Q. leucotrichophora* A. Camus), which are degraded and non-degraded forests in the Lamgarha block of the Kumaun Central Himalaya. Soil moisture showed a direct relationship with precipitation. The study reported no distinction in soil water holding capacity irrespective of seasons, but slightly higher in winters followed by rainy and summer seasons. Soil porosity, bulk density, pH, organic matter, and other soil nutrients are significantly higher in the non-degraded oak site. Ors *et al.* (2010) worked on the physical and chemical soil properties of orchid growing areas in eastern Turkey. They evaluated the differences in soil properties according to orchid species (*Dactylorhiza* spp., *Orchis* spp.). They reported that the physical and chemical parameters of soil did not vary with regard to orchid species. The soils' microelements (Copper, Iron, Zinc, Cadmium, Lead, Chromium, and Manganese) content differed significantly from each other. The soils' chemical and physical analyses did not show any different results concerning orchid species but in locations' altitudes.

Soils from stable forest ecosystems have definite physical, chemical, and biological attributes considering the prevailing conditions in which they developed. Zornoza *et al.* (2007) studied the soil properties under natural forests in the Alicante Province of Spain. The establishment of two soil quality indices under Mediterranean semi-arid conditions for forest soils in SE Spain, based on multiple linear regressions integrating different physical, chemical, and biochemical properties, was reported. They observed the strong influence of climatic factors on various soil properties. They confirmed that a balance exists between the soil organic carbon of high-quality soils and some other properties widely recognized in soil quality assessments due to their sensitivity and the information they provide about the functionality of soils.

Bhat and Kaveriappa (2009) studied the physicochemical attributes of the soils of myristica swamp forests in Uttara Kannada. The study reported that the soil was silty and sandy loam acidic to neutral pH and had moderate organic carbon levels. Soil nitrogen, phosphorous, and potassium contents were in the range of 0.64-1.26%, slightly lower than in other forest ecosystems of the region. Kumar *et al*. (2010 a) studied the tree species diversity and soil nutrient status in three tropical dry deciduous forest sites in western India. The study observed that all the individual soil variables showed a high positive correlation with tree species richness. In contrast, tree density showed a clear negative correlation with phosphorous and nitrogen and a positive correlation with carbon.

Balagopalan and Jose (1995) compared the soil properties of natural evergreen forests and adjacent exotic plantations of eucalyptus and rubber in Kerala. They observed moderate acidity in both natural forests and plantations. Higher organic carbon, water holding capacity, cation exchange capacity, and total nitrogen and phosphorus were considerably reported for the natural forest. A similar study was carried out in natural forests and *Tectona grandis* and *Anacardium occidentale* plantations in Kerala. The soils were moderately acidic in all the vegetation types. The study observed significant variation due to vegetation in all the soil properties except for gravel, silt, P, Ca, and Mg (Balagopalan, 1995).

2.5.2. PHYSICOCHEMICAL PROPERTIES OF SOIL

The Physico-chemical properties of forest soils vary spatially and temporally due to climate variation, topography, weathering processes, microbial activities, vegetation cover, and numerous other biological and abiotic factors. Vegetation and soil interrelationship play a significant role in soil formation processes (Champan and Reiss, 1992). Several studies are available on different physicochemical characteristics of the soil. They are reported here below:

I. ORGANIC CARBON

Forest soil is an important depository of organic carbon. Soils' potential to store organic carbon is considered an essential function of soils crucial for climate regulation and influences the other soil functions. Environmental conditions such as clay mineralogy, natural vegetation, soil type, specific surface area, microorganisms, metal oxides, Ca and Mg cations, soil fauna, aggregation, texture, land use and management, topography, parent material, and climate as environmental conditions that affect soil organic carbon (SOC) storage spatially and temporally from micro-scales to the global scale (Wiesmeier *et al*., 2019).

Evrendilek *et al*. (2004) investigated the effects of changes in soil organic carbon (SOC) content and other physical soil properties over 12 years in three adjacent ecosystems on the Mediterranean plateau of Turkey. They observed that grassland conversion into cropland during the last 12 years decreased SOM by 48.8% and soil organic carbon (SOC) content by 43%. They concluded that the correlation matrix revealed that SOC content was positively correlated with available water capacity, total porosity, mean weight diameter, forest, and grassland, and negatively correlated with bulk density, pH, and soil erodability.

Maro *et al.* (1993) studied soil chemical characteristics of natural forest and a *Cupressus Lusitanica* plantation on west Kilimanjaro, Northern Tanzania. They observed that the natural forest had higher amounts of organic matter, total nitrogen, and exchangeable sodium in some soil horizons than the plantation, but greater acidity in the organic layer of the plantation than that under the natural forest was reported.

Tsui *et al.* (2004) examined the spatial differences in soil properties in southern Taiwan's lowland evergreen broad-leaved rain forest. They reported high organic carbon, available N, available K, extractable Fe, and exchangeable Na on the summit, while pH, available P, exchangeable Ca, and Mg were significantly higher on the foot slope. They concluded that organic carbon increased with increasing altitude, apparently resulting from the quality of litterfall and a lower decomposition rate in the summit forest.

Joshi *et al.* (2013) observed soil organic matter was maximum (5.68 %) in high altitude forests and minimum (3.76%) in low altitude forests at the site of soil in the protected forest ecosystem of the Askot Wildlife sanctuary. Soil organic carbon of the Garhwal region's temperate forest was studied by Saha *et al.* (2018) and reported that the percentage of organic carbon in the Dhanaulti forest was between 0.14 and 0.19%. However, the organic carbon showed no specific trend with increasing depth levels for all three seasons. However, the highest percentage of organic carbon was reported at higher altitudes during the rainy season.

High-altitude soils potentially store a large pool of carbon. Tashi *et al.* (2016) examined the effects of altitude and forest composition on soil C and N along a transect from 317 to 3300 m a.s.l. in the eastern Himalayas. They emphasized that soil's total C and N content significantly increased with altitude but decreased with soil depth. Soil organic carbon of temperate coniferous forests of Northern Kashmir was documented (Dar *et al.,* 2015). The study reported that conductance, moisture content, organic carbon, and organic matter were significantly higher while pH and bulk density were lower at the Gulmarg forest site.

Bharali *et al.* (2014) examined the variations in soil physicochemical properties in space and time and their impacts on 3 Rhododendron species' growth in a temperate forest in the eastern Himalayas. Soil samples were collected from different soil depths and analyzed on a seasonal basis for two consecutive years from 3 different study sites along an elevation gradient. Soil physicochemical properties showed significant variations with depth, season, and elevation. Gosain *et al.* (2015) compared the vegetation patterns and physicochemical properties of soils of the oak and pine forests of the Khulgad watershed (District Almora in Uttarakhand), focusing on carbon stock in vegetation and soil pool. C-sequestration in the vegetation pool was also estimated. The study documented that oak forests were rich in all the physicochemical properties as compared to pine forests. Oak forests were characterized by high SOM, soil moisture, WHC, and soil fertility (N, P, K), and all the soil nutrients in these forests decreased with increasing soil depth.

Mishra *et al*. (2017) the organic carbon of different forest sites in the tropical semi-evergreen forest of the Eastern Himalaya. The study observed the variation in the organic carbon with 0.65-4.05 % at 0-30 cm depth, 0.32-3.03 % at 31-45 cm depth and 0.25-3.04 % at 46-90 cm depth respectively. Kumar *et al.* (2010 b) observed a decrease in organic carbon with depth increase in their study of the dry tropical forest of Rajasthan. Also, most of the soils sampled had rather high values for organic C (mean value, 6.78%) in the top horizons, with organic carbon decreasing down the profile.

II. pH

By definition, soil pH is a measure of the activity of hydrogen ions in the soil solution. Soil pH influences plant potential for nutrient uptake and tree growth. The soil's nutrient availability is dynamic due to soil reactions, primarily controlled by soil pH. Trees may or may not be able to use nutrients because of these reactions. Soils with a pH of 6.0-7.0 typically have high concentrations of available nutrients (Williston and LaFayette, 1978).

Chen *et al.* (1997) worked on soil chemical properties of the subtropical rainforest of Nanjenshan Reserve, southern Taiwan, and reported that the soil pH, available N, CEC, exchangeable Al, K, Ca, and Mg differed significantly among the landforms. The soil pH levels, exchangeable Ca, and Mg exchangeable Al tended to increase in the downslope direction slope soils, while exchangeable Al tended to be higher in the upper slope soils. Joshi *et al*. (2013) described the soil of the protected forest ecosystem of Askot Wild Life Sanctuary as acidic in nature, with a pH value ranging from 5.3 to 6.5.

Saha *et al.* (2018) analyzed the soil of the temperate forest of the Garhwal region. They found the pH values ranged between 6.33 and 6.75, which was slightly acidic. Soils within forest ecosystems are not static but rather change spatially and temporally. Bharali *et al.* (2014) examined the spatial and temporal variations in soil physicochemical properties and their impacts on the growth of 3 *Rhododendron* species in a temperate forest in the eastern Himalayas. The study observed significant variations in soil physicochemical properties with depth, season, and elevation. The pH showed positive correlations with the growth in the height of R. *kendrickii* and R. *grande*, while that of R. *mechukae* indicated a negative correlation.

III. CATION EXCHANGE CAPACITY (CEC)

Virtually all the plant nutrients are taken in their ionic form in the soil from the solution. The insight of the nutrient turnover rate contributes to the valuable information into the soil nutrient availability and the biochemical process (Robertson *et al*., 1999). Cations are positively charged ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}), sodium (Na^{+}) hydrogen (H^{+}), aluminum (Al^{3+}), iron (Fe^{2+}), manganese (Mn^{2+}), zinc (Zn^{2+}) and copper (Cu^{2+}). The soil's capacity to hold on to these cations is called the cation exchange capacity (CEC). These cations are bound by the soil's negatively charged clay and organic matter particles through electrostatic forces (negative soil particles attract the positive cations). The cations on the CEC of the soil particles are easily exchangeable with other cations. Consequently, they became available for the plant. Therefore, the CEC of soil forms the total amount of exchangeable cations that the soil can utilize. Plants utilize a relatively greater size of calcium, magnesium, and potassium cations.

Soil organic matter is a crucial component of the soil. It is generally considered to account for a large portion of the cation exchange capacity of soils low in clay. That exchange capacity, specifically organic materials, is distinctly pH-dependent (Coleman *et al.,* 1959) analyzed soils of the North Carolina Piedmont for permanent and pH-dependent charge components of cation exchange capacity. Helling *et al.* (1964) determined the effect of pH of the buffered saturating solution on the cation-exchange capacity (CEC) of 60 Wisconsin soils. Also, they measured the relative contributions of clay and organic matter to total CEC. They observed that the CEC of both clay and organic matter increased linearly with pH. The regression equations indicated that the mean relative contribution of organic matter to total soil CEC in this group of soils varied from 19% at pH 2.5 to 45% at pH 8.0; the soil studied had a mean organic matter and clay content 3.28% and 13.3% respectively. Pratt and Bair (1962) carried out a survey and analyzed the cation-exchange properties of some California acid soils. The study reported a continuous change in CEC with a pH change, while data on others showed a constant value between pH 3 and 4.5 with increases as the pH increased from 4.5 to 8.0.

IV. ELECTRICAL CONDUCTIVITY

The soil's electrical conductivity measures the number of salts in the soil (salinity of soil), which is an essential index of soil health and productivity. It significantly influences the plant's nutrient availability and the activity of soil microorganisms. Soil electrical conductivity can be an indirect index of the soil's different physical and chemical properties (Sudduth *et al*., 2005). It relates to soil electrical conductivity data and determines soil properties across various soil types, climatic conditions, and management practices of the north-central USA.

According to a study conducted by (Reyhan and Amiraslani, 2006), electrical conductivity had significant effects on vegetation. Dar *et al*. (2015) examined the electrical conductivity of temperate coniferous forests in northern Kashmir. They observed the variation in soil electrical conductivity value across all the sites, with the highest value of 211.00± 33.84 (μS/cm) and 141.33± 19.20 (μS/cm) as the lowest value. The electrical conductivity of soil is influenced by variation in sites, soil depth, and interaction between them and reported the electrical conductivity of forest soil of *Cedrus deodara* (Digvijay *et al*., 2020). They observed a variation in electrical conductivity from 0.07 to 0.17 dSm^{-1} with a maximum value of 0.23 dSm^{-1}. The study also observed a significant decrease in electrical conductivity with an increase in soil depth.

V. BULK DENSITY

Soil bulk density (q) is an essential physical attribute; it is the soil's weight in a given volume. Bulk density measurement is usually lacking in soil surveys because of its difficulty and time consumption (Jalabert *et al.,* 2010). They used the Generalized Boosted Regression Modelling technique that combines two algorithms: regression trees and boosting, and built two models and compared their predictive performance with published pedotransfer functions (PTFs). The functions were fitted based on the French forest soil dataset for the European demonstration Biosoil project. The two GBM models were Model G3, which involved the three most frequent quantitative predictors used to estimate soil bulk density (organic carbon, clay, and silt), and Model G10, which included ten qualitative and quantitative input variables as parent material or tree species.

Amponsah and Meyer (2000), in their study, compared the soils of natural forests converted to a plantation in the moist semi-deciduous forest zone. They observed that bulk density significantly increased in the 0-20 cm depths (1.17 to 1.30 g cm^3) while the other physicochemical properties significantly decreased where natural forests were replaced with teak plantations. In the moist temperate forest of the Mandal-Chopta area in the Garhwal region of Uttarakhand, the bulk density value ranged between 0.79 g cm^{-3} and 1.29 g cm^{-3} (Sharma *et al.,* 2010).

Mishra *et al.* (2017) investigated the soil of different forest sites in the tropical semi-evergreen forest of the Eastern Himalaya. The bulk density ranged from 0.80 -1.10 g cm^{-3} for 0-30 cm depth, 0.93-1.15 g cm^{-3} for 31-45 cm depth and 0.88-1.15 g cm^{-3} for 46-90 cm depth respectively. Soil physicochemical characteristics varied among vegetation types, primarily in bulk density (Guo *et al*., 2016), reported at a rate of 1.35 g·cm^{-3} for native forest, a 1.33 g·cm^{-3} mixed forest, and 1.27 g·cm^{-3} for tea garden. Bulk density significantly decreased from broadleaved forests to tea gardens.

2.6. GEOGRAPHIC AND INFORMATION SYSTEM (GIS)

Assessing the forest ecosystem structure and composition over a large and remote area is usually complex and arduous. Still, GIS provides information essential for modeling multiple-use forest management decisions. The knowledge of remote sensing, geographic information systems (GIS), and global positioning systems (GPS), are the modern tools for the assemblage and manipulation of such information. Remote sensing imagery from a large variety of space-borne and airborne sensors provides a vast amount of data about our earth's surface for global and detailed analysis, change detection, and monitoring (Benz *et al.*, 2004). Advances in remote sensing science and our ability to analyze temporal changes in our landscape hold great promise for putting to rest any questions about the relevancy of remote sensing to local land-use decisions (Civco *et al.*, 2002). Satellite images can show larger areas. As a satellite regularly passes over the same plot of land, capturing new data shows a change in land use, and conditions can be routinely monitored. In the Land Monitor Programs, satellite images are being used to provide information on land conditions and the changes in those conditions over time, precisely the status of remnant vegetation, to help farmers, environmental managers, and planners better manage the land.

Modern technologies such as remote sensing and geographical information systems provide some of the most accurate means of measuring the extent and pattern of landscape changes over time (Miller *et al.*, 1998). The remote sensing and geographic information system (GIS) in assessing forest cover changes between 1931 and 2001 in the Kalrayan Hills, Tamil Nadu, showed the trend over 70 years was analyzed using high-resolution satellite data. They noticed that forest cover had increased between 1931 and 1971 because the forest department implemented various afforestation schemes and scared grooves. It also revealed that the forest cover loss between 1971 and 2001 could be due to shifting cultivation and illegal encroachments. The forest cover has drastically decreased in plateau areas due to human population pressure. The study analyzed forest cover change in the tropical deciduous forest region of the Eastern Ghats of India. It was envisaged that the investigation would prove the usefulness of Remote Sensing and GIS in forest restoration planning (Sakthivel *et al*., 2011).

Corrigan *et al.* (2010) used a series of seven aerial photos, dating from 1937 to 2008, to quantify changes in the land-cover type and classified them into core forest, regrowth forest, and open areas (open woodland and anthropogenically altered land) on the Kwanibela Peninsula, St Lucia, South Africa. The study also compared the percentage of each forest cover across the years to assess the complete vegetation change and change direction. The overall species attributes at different stages of forest succession in the study were presented as supplementary information.

Poorter and Weiringa (2001) developed an effective conservation policy using GIS for rare and endemic plants. Godefroid and Koedam (2003) studied species composition in the forest edges (city zone) and the neighboring forest interior in Brussels, Belgium using GIS and RS. They observed that urbanization affected the flora of neighboring semi-natural areas (forest edges) by allowing alien species to invade. Sudeesh and Reddy (2012) studied the vegetation and land cover mapping of the Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India, using Remote Sensing and GIS. The study indicated that the forest cover was 2653.9 km^2, which was proportionately 61% of the total geographic area of NSTR. GIS analysis revealed that the open dry deciduous forest is the most dominant vegetation type, comprising 52.5% (1394.3 km^2) of the total forest stock in 2010.

Vegetation classification and mapping commonly generate a stable descriptive view of the vegetation resources. They are considered important in driving baseline information in ecosystem conservation (Ellenberg and Mueller-Dombois 1974, Wallace *et al*., 2006). Nevertheless, vegetation is dynamic, and its changes over time are debatably the most crucial information for management decisions. The knowledge of specific vegetation changes helps identify and quantify challenges, set targets, and assess responses to management actions (Wallace *et al*., 2006). Satish and Reddy (2016) used remote sensing data and studied long-term monitoring of forest fires in Silent Valley National Park, Western Ghats, India. The Multi-season Resources at-2 LISS III data was used for the vegetation type mapping.

Kim *et al.* (2009) investigated the use of geographic object-based image analysis (GEOBIA) approach with the incorporation of object-specific grey-level co-occurrence matrix (GLCM) texture measures from a multispectral Ikonos image for the delineation of deciduous, evergreen, and mixed forest types in North Carolina. The spatial autocorrelation of each segmentation was evaluated by calculating Moran's I using the average image digital numbers (DNs) per segment. The automated segmentation yielded information comparable to manually interpreted stand-level forest maps regarding the size and number of segments. The results demonstrated that the scale of segmentation directly influenced the object-based forest type classification. (Leprieur *et al.,* 2000) compared the remote observations on various scales and monitored the vegetation cover across the semi-arid region. Detailed vegetation mapping is crucial to natural resource management and vegetation assessment.

Su *et al.* (2016) employed the strategy of multispectral aerial imagery and LiDAR. They mapped the vegetation composition and structure over a large spatial scale. The study determined to develop several vegetation groups within the mixed conifers forest of Sierra Nevada in California. The approach recognized four and seven vegetation at the two study locations. Each vegetation group has its distinguished vegetation composition, with the accuracy and Kappa coefficient of vegetation mapping of over 78 percent.

The GIS technique helps develop a tree mapping system and create a geodatabase for spatial analysis. Hasmadi (2010) determined phytosociology and mapped out the vegetation of Mount Tahan, Malaysia, using GIS. The study focused on the altitudinal distribution of specific plant communities between 1900 m and 2140 m. The phytosociological classification revealed that untrammeled areas in Botak and Puncak sites were higher in species and more diversified communities than the trampled areas. Gianguzzi (2016) reported that photo-interpretation and field validation allowed the identification of 36 phytocoenotic types, divided into zonal (communities tied to the various bioclimatic belts, in particular maquis, woods, garrigues, and semi-natural grasslands), zonal (coenoses typical of habitats conditioned by the substrate, such as cliffs, streams, coastal dunes, etc.) and anthropogenic vegetation.

Materials and Methods

MATERIALS AND METHODS

The present study investigated the phytosociology and physicochemical properties of soil and the land use and land cover changes of the Shendurney Wildlife Sanctuary, Kollam, Kerala. The study was carried out for a period of two years, from September 2018 to October 2020. The details regarding the study area, experimental site, and the methodology adopted for data collection and analysis are detailed below.

3.1. STUDY AREA

3.1.1. Name, Location, and Extent

The Shendurney Wildlife Sanctuary is named after a local tree called "Chenkurinji" (*Gluta travancorica*), an endemic tree found only in this area. The Sanctuary is located between the geographical extremes of 8 44' and 9 14' N latitude and 76 59' and 77 16' E longitude in Thenmala, Kollam district of Kerala state (Fig.1). The Sanctuary is part of the Agasthyamalai Biosphere Reserve, one of the Western Ghats' most biodiverse areas. According to notification number G.O (P) 258/84/AD dated 25-8-1984, Shendurney was declared a wildlife sanctuary and was later transferred to the Thenmala Forest Division's administrative authority (KFD, 2014). However, as per notification number G.O (Rt), 117/86/F&WLD dated 19-3-1996, a separate wildlife division, namely Shendurney Wildlife Division, was established for the Sanctuary's better management. The Sanctuary has notified an area of 171 sq. km with well-defined natural boundaries. The present study inventoried the floristic composition of the major forest ecosystems of Shendurney, soil physicochemical properties and mapped out the ecosystem's boundaries to understand land cover changes.

3.1.2. Terrain

The terrain of the Shendurney Wildlife Sanctuary ranges from 100-1550 m above sea level. It is bounded east by the Sahyadri hills, which function as an excellent barrier disjoining the two states, Kerala and Tamil Nadu. The Sanctuary lies on either side of the Shendurney river and is located north of the Kulathupuzha valley, separated by the Churuttumala ridge. The entire area is hilly, with a gentle slope towards the west. The eastern portion near the high hills is very irregular, interspersed with ravines with a peak of 1550 m known as the Alwarkurichi peak.

3.1.3. Climate

3.1.3.1. Temperature

The area exhibits a substantial fluctuation in temperature, both seasonal and diurnal, due to the disparity in elevation, with the hottest months being March to May and the coldest, December and January. Summer rains bring down the temperature slightly during June and July. The maximum temperature during the daytime in the hottest month of the year is about 39˚C. The temperature varies between 17 and 35˚ C. The hot and humid climate favors the luxuriant growth of vegetation in the tract.

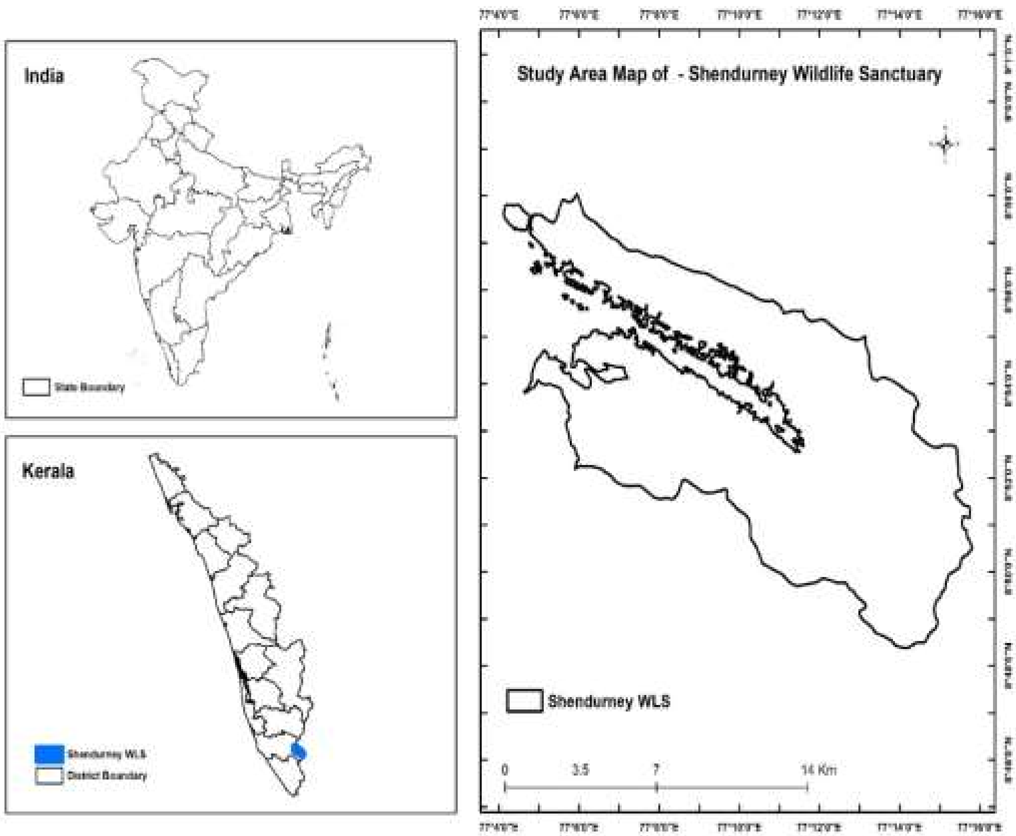


Fig. 1. Study Area Map (Field survey, 2020)

3.1.3.2. Rainfall

The Shendurney wildlife sanctuary receives rainfall during the dual (Southwest and Northeast) monsoon season, with a larger percentage (75%) of the precipitation occurring at the time of the Southwest monsoon from May to the middle of September. The Northeast monsoons are infrequent and often appear in the afternoons during October and November, followed by dry easterly winds, which are prominent for their damaging characteristics. Rainfall varies in intensity across the areas, but the annual rainfall is approximately 3200 mm (KFD, 2014).

3.1.4. Geology, Rock, and Soils

The Sanctuary is characterized by metamorphic rock mainly of charnokites and gneisses, with an intrusion of large masses of granite nature covering the significant area in the main ridges and slope. The fragmentation of granite gneisses resulted in the formation of excellent loam with a mixture of humus. This alters significantly according to the position of the slope. The fluctuation in the extent of disintegration from hard rock to fine gravel resulted in laterite formation. The alluvial deposit is found along the stream and riverbanks deep enough for sumptuous tree growth.

3.2. Vegetation

The Shendurney wildlife sanctuary forest displays noticeable changes in floristic composition due to altitudinal, climatic, and edaphic attributes. It is at the threshold of the Agasthyamalai hill ranges, exceptionally well known for its floral biodiversity richness and endemism. The vegetation displays precipitous and critical change from the Sanctuary forward. The vegetation was classified into west coast tropical evergreen forest, west coast tropical semi-evergreen forest, southern hilltop tropical forest, southern secondary moist mixed deciduous forest, ochlandra reed brakes, myristica swamp forest, and grasslands. All the forest types differ significantly in species composition with a change in elevation.

3.2.1. West Coast Tropical Evergreen Forest (1A/C4)

It is an evergreen forest classified as a tropical wet evergreen forest (Champion and Seth 1968). This type of forest is commonly found between elevations of 240 m to 1100 m. It can sometimes broaden to 1350 m and often with noticeable changes in the species composition and structure. In the upper storey, the forest consists of *Dipterocarpus indicus, Mesua ferrea, Mangifera indica, Vateria indica, Hopea parviflora, Palaquium ellipticum, Symplocos cochinchinensis, Kingiodendron pinnatum, Cullenia exarillata, Gluta travancorica* e.t.c. The middle- to lower-storey consist of *Dysoxylum malabaricum, Schleichera oleosa, Xanthaphylum arnottianum, Carallia brachiata, Baccaurea courtallensis,* and *Polyalthia fragrans* e.t.c.

3.2.2. West Coast Tropical Semi-Evergreen Forest (2A/C2)

The West coast tropical semi-evergreen forest is found between evergreen and moist deciduous and is usually identified as a transitional stage from evergreen to moist deciduous. It is observed that anthropogenic and environmental factors influence the appearance of species at both low and medium elevations. The forest of west coast tropical semi-evergreen forms a close high forest but mainly lower in quality than tropical evergreen forest. Species composition significantly varies with altitudinal change with *Dipterocarpus indicus, Mangifera indica*, *Tetrameles nudiflora, Syzygium cumini, Artocarpus hirsutus, Alstonia scholaris* e.t.c. found at the upper storey and *Buchanania lanceolata, Diospyros montana, Diospyros foliosa, Diospyros paniculata, Diospyros candolleana, Aporosa cardiosperma, Lagerstroemia microcarpa, Vitex altissima etc*., at middle storey while lower storey comprises species such as *Memecylon talbotianum, Syzygium mundagam, Ixora brachiata, Tabernamontana alternifolia* etc.

3.2.3. Southern Secondary Moist Mixed Deciduous Forest (2A/C3)

The southern secondary moist mixed deciduous forest is seen virtually in all Sanctuary parts, mostly down 600 m elevation. This forest is classified based on the domination of species, primarily deciduous, exceptionally light demanders attending up to a height of 30-35m and with fewer evergreen species usually at the lower elevation. The notable appearance of this type of forest ecosystem is the leafless period during the dry season. At this time, the upper canopy is approximately entirely leafless, and the formation of an inadequate amount of regeneration of evergreen species. This forest type is mainly confined to the low elevation places at Thenmala, Kattilappara, and Rosemala. *Pterocarpus marsupium, Terminalia paniculata, Terminalia crenulata, Terminalia bellirica, Lagerstroemia microcarpa, Tetrameles nudiflora, Sterculia guttata, Bombax ceiba,* e.t.c are generally found at the upper storey, the middle storey is constituted of *Aporosa cardiosperma Olea dioica, Hymenodictyon obovatum, Alstonia scholaris, Buchanania lanzan, Careya arborea, Miliusa tomentosa, Pongamia pinnata,* etc. *Wrightia tinctoria, Naringi crenulata, Mallotus philippensis, Chionanthus mala-elengi,* etc., at the lower storey.

3.2.4. Myristica Swamp Forest (4C/FS1)

This is a unique forest type found exclusively in the plains and low elevations of the Western Ghats' southernmost part. It is portrayed by edaphic formation formed in the bottom of the valleys, experiencing the inundation throughout the year. These swamps are found mainly in the poorly drained zone with a continued rainy season, restricted to the inactive streams as fringing forest below 300 m elevations. The peculiarity of this unique forest type is the profusion of the species of the Myristicaceae family. This is a special forest type found exclusively in the plains and low elevations of the Western Ghats' southernmost part. It is characterized by edaphic formation formed in the bottom of the valleys, experiencing inundation throughout the year. The forest is mainly dominated by species belonging to Myristicaceae in association with other low elevation evergreen trees.

3.2.5. Southern Hilltop Tropical Evergreen Forest (A1/C3)

This type of forest is generally found on the top of hills, the ridge in the upper portion of Kallar, beyond Pandimotta, and in certain pockets near the interstate boundary. The forest is confined to an altitude ranging between 1000 m to 1300 m. and more or less an inferior edition of the wet evergreen forests of lower elevations. Trees are identified by their lower height growth rarely exceeds 20 m. The height growth restriction is due to high wind velocity. Transition is usually found between this forest type and the tropical wet evergreen forests at an elevation above 1200 m. *Cinnamomum sulphuratum, Calophyllum polyanthum, Hydnocarpus alpina, Elaeocarpus munronii, Garcinia cowa, Casearea macrocarpa, Litsea keralana, Litsea floribunda, Litsea coriacea, Litsea oleoides, Actinodaphne malabarica, Neolitsea scrobiculata Vernonia travancorica, Symplocos cochinchinansis, Syzygium densiflorum* etc.

3.3. Vegetation Analysis

3.3.1. Floristic Survey

A reconnaissance survey was carried out to locate the sample plots for phytosociological analysis. The secondary data maintained for the area was collected from records at Shendurney Wildlife Sanctuary. Phytosociological data was collected from the forest types using a stratified random sampling method, with forest types as primary strata and elevation gradients as substrata. A thorough survey and comprehensive field trip and camping for data collection were conducted periodically for two years, from September 2018 to February 2020. The forest ecosystems of Shendurney are mainly disconnected, while few of the ecosystems are accessible on foot. Soil samples were collected from a specific quadrat for studying edaphic attributes in different forest ecosystems.

3.3.2. Phytosociological Survey

The study was conducted in all the major forest ecosystems of the Shendurney Wildlife Sanctuary. The phytosociological analysis was carried out following the standard method (Mueller-Dombois and Ellenberg, 1974). Phytosociological data was collected from all the forest types based on the stratified random sampling method. Quadrates were laid from the forest types representative, and variation in their altitudinal zonation was considered. Structural data was collected from a sample quadrate of 20 m x 20 m in size laid in different forest types. Two subplots of 5m×5m were laid in two corners of each 20m × 20m for saplings and four 1m×1m in the four corners of the main plots for assessing tree seedlings. The sampling intensity varied significantly among the forest ecosystems and were considered based on the size of the ecosystems; the west coast tropical semi-evergreen forest constituted the higher sampling area of 22000 m^2 followed by 20000 m^2 for west coast tropical evergreen, 15200 m^2 for southern secondary moist deciduous, 8000 m^2 for the tropical hilltop forest wheareas 2700 m^2 for the myristica swamp forest respectively. All the trees ≥ 10 cm were enumerated, and for other individual species, <10cm were measured as regeneration (for tree saplings individuals 5.3-9.6 cm DBH, >1m height, and individual <5.3 cm DBH ≥30 cm height as seedlings were considered as established seedlings and saplings) (Misra, 1968; Reddy *et al*., 2007). Individual trees with multiple stems near the ground were measured as a single individual, while an individual with buttresses was measured up to 2 m above the buttresses. All the individual trees species enumerated were identified by consulting taxonomists and dendrologists and by referring to published sources such as Gamble and Fisher (1915-1936), Pascal and Ramesh (1987), Flowering Plant of Kerala Version 2.0 (Sasidhran, 2012), Flora of Peninsular India by IISc, Centre for Ecological Science (2019) and by consulting plant taxonomist.

The data obtained was recorded to find out the following: density, abundance, relative frequency, relative density, percentage frequency, basal area, and importance value index by using the standard formulae. Additionally, various diversity indices, such as the Shannon–Wiener diversity index (Shannon and Weiner, 1963), Simpson index, Pielou's index of evenness (Magurran, 1988), distribution pattern, Index of similarity between the community (Sorenson), and concentration of dominance were worked out for various ecosystems encountered in the Sanctuary.

3.4. Phytosociological analysis

3.4.1. Numerical Analysis

The primary analysis of floristic inventory was carried out to ascertain the values of different parameters like frequency (F), density (D), abundance (AB), relative frequency (RF), relative density (RD), relative basal area (RBA), and important value index (IVI) (Curtis, 1959).

i. Frequency

Frequency refers to the extent of dispersion of individual species in an area, generally expressed in percentage occurrence. It was studied by sampling the study area randomly at several places and recording the names of the species that occurred in each sampling unit. It is calculated by the equation below:

$$\text{Percentage Frequency} = \frac{\text{Number of quadrats of occurrence}}{\text{The total number of quadrats studied}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Number of occurance of a specie}}{\text{Number of occurance of all the species}}\ 100$$

ii. **Density**

Density is an expression of a species' numerical strength where the total number of individuals of each species in all the quadrates is divided by the total number of quadrates studied. Density is calculated by the equation as follows

$$\text{Density} = \frac{\text{Number of Individual of the species in all the quadrat}}{\text{Total number of quadrats studied}}$$

Relative density (RD) is the study of the numerical strength of species in relation to the total number of individual of all the species, calculated as

$$\text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} \times 100$$

iii. Abundance

Abundance is an expression of a number of individual of different species in the given community per quadrat in which the species occurred expressed as follow:

$$\text{Abundance} = \frac{\text{Total number of individual of a species in all the quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

1. Girth Class Distribution

All the individual plants sampled from the studied quadrat were classified into different groups based on their girth class distribution, i.e., 10-30 cm, 31-60 cm, 61-

120 cm, 121-180 cm, 181-210, and >210 cm. Individual plants with less than 10 cm circumference were taken as regeneration.

2. **Basal Area/ Dominance (BA)**

The total basal area was calculated from the sum of the total diameter of emerging stems. In trees, poles, and saplings, the basal area was measured at a breast height of 1.37 m.

Basal area = $G^2/4\pi$ (G= Girth at breast height)

iv. **Importance Value Index**

The importance value index gives the total status of the species for community structure. To obtain this value, the percentage value of relative frequency, relative density, and the relative basal area are summed up, and the obtained value is described as the importance value index of the species (Curtis and Mcintosh, 1950). It was assessed using the following formula.

Important Value Index = Relative density + Relative Frequency +Relative basal area

3.5. Plant Diversity indices

3.5.1.1. Species Diversity

Shannon's index and Simpson's index of diversity indices were calculated using the following formulas:

i. Shannon and Wiener's Index (H') Shannon (1968)

(a) $H' = 3.3219 (\log N - 1/N \Sigma n_i \log n_i)$

(b) $H_{max} = 3.3219 \log_{10} S$

Hmax is the maximum dispersion taking into account the number of species in the plot

Where, N- Total number of all the individual of all the species

ni- Number of individuals of a species

S- Total number of species

3.3219 the conversion factor $\log_2$ to $\log_{10}$

ii. Concentration of Dominance

The concentration of dominance is a measure at which community differs in how some measure of importance is shared among the species. Simpson Index (1949) is used to examine the concentration of dominance.

iii. Simpson's Index (D) (Simpson, 1949)

$$\lambda = \frac{\Sigma \text{ (ni (ni} - 1)}{\text{N (N} - 1)}$$

Where ni is the was the total number of individuals of species i

Modified Simpson's index = λ/1

N= total number of all the individuals of all the species

iv. Similarity Index

Jaccard (1912) extends the similarity index concept to compare two plant communities that mirror each other in appearance. This concept is based on the species presence and absence relationship between the plants between the two areas and the total number of species.

Sorenson's index of similarity (Magurran 1988)

$$Sorenson's\ index\ = \frac{2a}{2a + b + c}$$

Where,

a= Total number of species that occurred in both the communities

b= Total number of species in a second community only

c=Total number of species in the first community only

3.6. Distribution pattern of the species

The abundance to frequency ratio was estimated to establish the species distribution pattern in the forest ecosystems (Curtis and Cottom, 1956).

3.6.1. Cluster Analysis

The divisive clustering was done in the species dataset, S, to analyze the species compositional similarity among the sites. This was examined using the command given by Kindt and Coe (2005).

3.6.2. Ecological distance analysis by ordination

The Detrended correspondence analysis (DCA) was employed in the species matrix to analyze various species assemblages in the forest ecosystems. This analysis was carried out using the BiodiversityR statistical software. This was examined using the command given by Kindt and Coe (2005).

3.7. Soil Analysis

Soil samples were collected according to the horizon wise up to one-meter depth from each ecosystem's representatives from April to June 2019. The samples were taken to the laboratory in a polythene bag, air-dried, and sieved through a 2 mm sieve. The samples were stored for physical and chemical analysis.

3.7.1 Soil Physicochemical Properties

3.7.1.1 Bulk density

The soil sample was collected for bulk density determination using the core sampling and gravimetry method (5 cm diameter), kept undisturbed. The samples were then placed in an airtight container and oven-dried at 105˚C until the constant weight was obtained in the laboratory. The bulk density was determined by dividing the weight by the sample volume.

3.7.1.2 pH (Hydrogen ion concentration)

The soil pH values were determined using a glass electrode digital pH meter with a soil and water ratio of 1:2.5 Ten grams of sieved, air-dried soil sample was taken in a 50 ml beaker, and 25 ml of water was added. It was stirred at a regular interval of half an hour. It was then allowed to settle for half an hour. The residue was taken for pH measurement. The pH meter was standardized using pH 4 and 7 buffer solutions.

3.7.1.3 Electrical conductivity

Soil electrical conductivity (EC) measures the number of salts in soil (soil salinity) directly related to its specific conductance. The electrical conductivity (EC) of the soil samples was determined in 1:2.5 soil water suspension with an electric-conductivity meter, Eutech CON 700, respectively, by adopting a procedure (Gliessman, 2000).

3.7.1.4 Organic Carbon

Organic carbon was obtained by the Walkley-Black method (Walkey and Black, 1934). One gram of sieved, air-dried soil sample was taken into a dry 500 ml conical flask. Ten milliliters of 1N $K_2Cr_2O_7$ were pipetted into it and swirled a little. The flask was kept on an asbestos sheet. Twenty milliliters of concentrated sulphuric acid were again added and swirled 2-3 times. The conical flask was allowed to stand for 30 minutes. After that, 200 ml of distilled water was added to terminate the reactions. Four to five drops of ferroin indicator were added. The content was titrated with ferrous ammonium sulfate solutions until the dark green to chocolate brown color illuminated intermittently.

3.7.1.4 Cation Exchange Capacity

Four grams of soil were transferred into a 500 ml conical flask and treated with 0.1M of $BaCl_2$. The content was shaken occasionally for two hours. The content was then filtered through a Whatman No. 42 filter, and the filtrate was collected in a flask. The exchangeable cations are extracted using the Atomic Absorption Spectrophotometer (AAS) for Calcium and Magnesium (Ca and Mg) and a flame photometer for Sodium and Potassium (Na and K) (Hendershot and Duquette, 1986).

3.8. Land cover classification and change analysis

The study area was classified using selected clear and cloud-free Landsat images: July 01, 2001, and January 14, 2018. The Shendurney Wildlife Sanctuary area is entirely contained within Landsat Path 143 and Raw 054. The overall image was rectified to geo-referenced to the Universal Transverse Mercator (UTM) projection zone 43 and WGS 84 datum using at least 205 and 94 well-distributed ground control points and nearest neighbor resampling. The root mean square errors were 4.21 m for the 2001 image and 8.41 m for the 2018 image. The image was processed using ArcGIS 10.1 and QGIS 2.18 versions. The land use and land cover mapping were successful by interpreting Landsat (ETM±) satellite images, 2001 generated and Landsat 8 OLI-TIRS images, 2018 generated.

3.8.1. Image processing

3.8.1.1. Training

This study adopted the land cover and land use classification developed by (Anderson 1976) to interpret remote sensor data at different scales and resolutions. The land use and land cover are categorized as different forest land, waterbody, open forest, and degraded area, according to the Anderson land-use/cover classification scheme. Prior to the field visit, an unsupervised image classification system was used to assess strata for ground truth. Fieldwork was carried out to collect data for training and validating land-use/land-cover analysis from the 2001 satellite image and for qualitative description of each land-use/cover class's characteristics. To make a testing sample set, a set of testing points is chosen at random.

3.8.1.2. Allocation

The ArcGIS 10.1 and QGIS 2.18 software were used for carrying out the image classification. Firstly, the Supervised classification with a Maximum Likelihood Algorithm based on the 168 training samples, the 2001 image, and 168 samples for the 2018 images was employed. Secondly, the supervised image classification techniques appropriate for the Maximum Likelihood Classifier (MLC) and 168 training samples were applied to produce the land use and cover maps of 2001 and 2018 (Richards and Richard, 1999). Lastly, a 3*3 majority filter was utilized for each classification to recode isolated pixels classified differently than the majority class of the window.

3.8.1.3. Accuracy assessment

An error matrix was developed to ensure the consistency of information obtained from remotely sensed data for accuracy assessments. The sample points were collected and confirmed by comparing the remote sensing study results to reference or ground truth data (Congalton and Green, 1999). An independent sample of 168 polygons with approximately 100 pixels per polygon was randomly selected from each classification to assess the classification accuracy. Classification accuracy was evaluated using error metrics such as cross-tabulation of mapped class vs. reference class (Congalton and Green, 1999). The error matrices were used to calculate overall precision, user and producer accuracy, and the Kappa statistic. The Kappa statistic incorporates the error matrices' off-diagonal aspects and represents agreement after discarding the agreement that may occur by coincidence.

3.8.2. Change detection

A multi-date post-classification comparison change detection algorithm was used to assess changes in land cover in the time intervals following the classification of imagery from individual years, which is the most widely used method of detecting changes (Jensen 2004). The "from-to" change information provided by the post-classification method can be easily calculated and mapped. The types of landscape transformations that have occurred can be easily calculated and mapped.

3.9. Statistical Analysis

The soil data were subjected to statistical analysis using the factorial CRD to determine the various physicochemical properties of the soil and the interaction with various depths. The correlation analysis was also conducted to test the significance level among the soil physicochemical parameters using SPSS V.25.0. Different floristic diversity analysis was carried out using the PAST(Paleontological Statistics) software 4.03 version. The detrended correspondence analysis and the cluster were analyzed using the BiodiversityR (R statistical software Version. 3.6.3).

Plate 2. Soil profiles and samples collection

Plate 1. Soil physicochemical analysis

Results

RESULTS

The present study was carried out during 2018-2020 in the major forest ecosystems of Shendurney Wildlife Sanctuary Kollam, viz; west coast tropical evergreen, west coast tropical semi-evergreen, southern secondary moist deciduous, southern hilltop tropical, and myristica swamp forest. The phytosociology of the forest ecosystems of Shendurney Wildlife Sanctuary was studied both at the tree level and that of understorey vegetation to achieve a floristic inventory of its major forest ecosystems. This study also accounted for the regeneration of the forest ecosystems, which is a prerequisite to the apparent nature of the future vegetation under the usual environmental conditions of that particular ecosystem. The data obtained from the present study generates a piece of information that is paramount to understanding the phytosociological characteristics of plant species in the three distinct strata, i.e., upper strata (large trees, gbh ≥10cm), middle storey (saplings, and seedlings of gbh< 10cm) in all the five major forest ecosystems of the Sanctuary. Soil samples from the representative of each ecosystem were collected from April 2019 to March 2020 at different depths, i.e., 0-10, 10-30, 30-60, 60-100 cm, respectively. The samples were analyzed for various physicochemical properties. Mapping for change detection of the forest ecosystems of Shendurney Wildlife sanctuary was also done to understand the trend in the ecosystems change resulting from various anthropogenic, natural, and climatic factors. The results obtained from this study are presented below.

4.1. SPECIES COMPOSITION AND VEGETATION STRUCTURE OF THE STUDY AREA

4.1.1 Spatial structure of tree community in west coast tropical evergreen forest

The west coast tropical evergreen forest (WCTE) constitutes the major proportion of the Shendurney Wildlife sanctuary. It was found in the low, medium, and higher elevations of the sanctuary. The vegetation enumeration revealed 119 species belonging to 92 genera and 47 families and a density of 1053.50 ha^{-1} and a basal area of 50.04 m^2 ha^{-1} from a total of 20,000 m^2 sampling area. Of all the documented species, 34 species are endemic to the Western Ghats, representing 27.73% of all the species, while 15 species are endemic to the Southern Western

Ghats, representing 14.29%. However, concerning conservation categories, three species, viz. *Aglaia malabarica*, *Anaclosa densiflora* and *Vateria indica*, are critically endangered (CE), 12 species are endangered (EN), 15 are least concerned (LC), two species are near threatened (NT), 12 species are vulnerable to extinction in the near future (VU) and two species are data deficient (Appendix XVII).

4.1.1.1. Girth class distribution

The girth class distribution of the evergreen forest was recorded for all the trees with a girth ≥ 10 cm (figure 2). The class distribution showed the reversed J shaped with decreasing density with increasing girth size and later raised at the highest girth class. The highest number of individuals trees was recorded in the lowest girth class ≥10-30 cm (796 species), representing 37.76% of the overall population. The lowest number (60 species), representing 2.84%, was recorded in the 181-210 cm girth class distribution. The highest girth ≥210 cm class has shown a good representation of 4.31 percent.

4.1.1.2. Relative importance of tree species in west coast tropical evergreen forest

In the west coast tropical evergreen forest, *Mesua ferrea* showed the highest importance value index of (IVI=12.52), followed by *Cullenia exarillata* (IVI=11.12), *Xanthophyllum arnottianum* (IVI=10.39), *Vateria indica* (IVI= 9.10), *Diospyros candolleana* (IVI= 8.86) and *Gluta travancorica* (IVI=8.36) (Table 1). The lowest importance value index (IVI=0.25) was recorded for *Dendrocnide sinuate* (Appendix I). The higher IVI value for *Mesua ferrea* and *Cullenia exarillata* is attributed to their relative density, relative basal area as well as relative frequency, while that of *Xanthophyllum arnottianum,* is attributed to their relative density and frequency. At the same time, the IVI for *Kingiodendron pinnatum* is due to the higher value of the relative basal area (Figure 3).

4.1.1.3. Abundance-frequency ratio

The abundance-frequency ratio of tree species in west coast tropical evergreen forest ranges between 3.00-0.08, and the highest value was recorded (3.00) for *Erythrina variegata* followed by (2.13) *Nothopodytes nimmoniana* and (1.50), *Celtis timorensis* and *Memocylon umbellatum*. All the individuals showed the value of AB/F greater than 0.05 (Appendix I).

4.1.1.4. Relative importance of families in west coast tropical evergreen forest

The dominant families in the west coast tropical evergreen forest are Dipterocarpaceae (FIV=24.92), Clusiaceae (FIV=21.40), Myrtaceae (FIV=20.78), Lauraceae (FIV= 19.48), Euphorbiaceae (FIV= 18.04), and Anacardiaceae (FIV=18.02) respectively (Table 2). The lowest family importance index (FIV=0.25) was recorded for the family Urticaceae. However, fourteen families have shown an importance value index of more than 10 (figure 4).

Table 1: IVI values of different species of west coast tropical forest (WCTE)

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BA	RBA	IVI
1	*Mesua ferrea*	6.04	0.13	72.50	6.88	48.00	4.09	0.78	1.55	12.52
2	*Xanthophyllum arnottianum*	7.85	0.20	78.50	7.45	40.00	3.41	0.13	0.26	11.12
3	*Cullenia exarillata*	6.24	0.18	53.00	5.03	34.00	2.90	1.24	2.47	10.39
4	*Vateria indica*	4.06	0.11	36.50	3.46	36.00	3.07	1.29	2.56	9.10
5	*Diospyros candolleana*	4.45	0.10	49.00	4.65	44.00	3.75	0.23	0.46	8.86
6	*Gluta travancorica*	4.20	0.14	31.50	2.99	30.00	2.56	1.42	2.81	8.36
7	*Dysoxylum malabaricum*	6.56	0.21	52.50	4.98	32.00	2.73	0.31	0.62	8.33
8	*Kingiodendron pinnatum*	1.40	0.14	3.50	0.33	10.00	0.85	2.74	5.44	6.62
9	*Baccaurea courtallensis*	4.53	0.15	34.00	3.23	30.00	2.56	0.07	0.15	5.93
10	*Persea macrantha*	3.53	0.12	26.50	2.52	30.00	2.56	0.41	0.82	5.89
11	*Carallia brachiata*	3.18	0.09	27.00	2.56	34.00	2.90	0.19	0.38	5.84
12	*Dalbergia lanceolaria*	1.00	0.50	0.50	0.05	2.00	0.17	2.78	5.51	5.73
13	*Syzygium densiflora*	5.10	0.26	25.50	2.42	20.00	1.70	0.71	1.41	5.54
14	*Hopea parviflora*	3.50	0.18	17.50	1.66	20.00	1.70	0.99	1.96	5.32
15	*Syzygium mundagam*	3.08	0.12	20.00	1.90	26.00	2.22	0.60	1.20	5.31

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; FIV- Family importance value of the species)

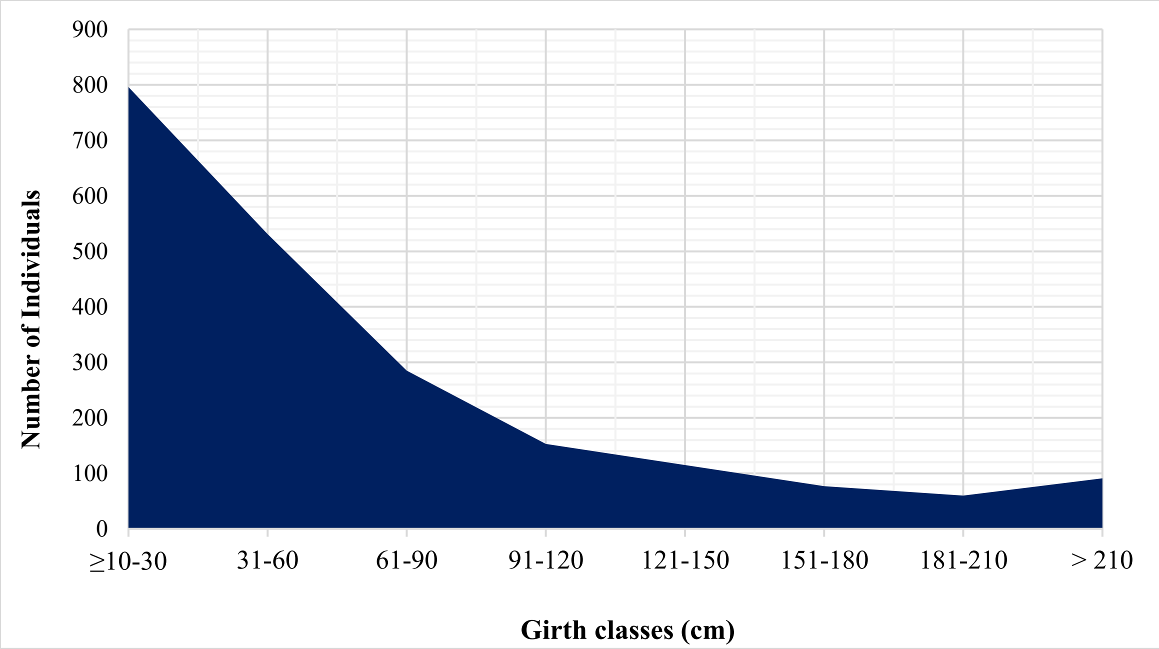


Figure 2. The girth class distribution of tree species of west coast tropical evergreen forest

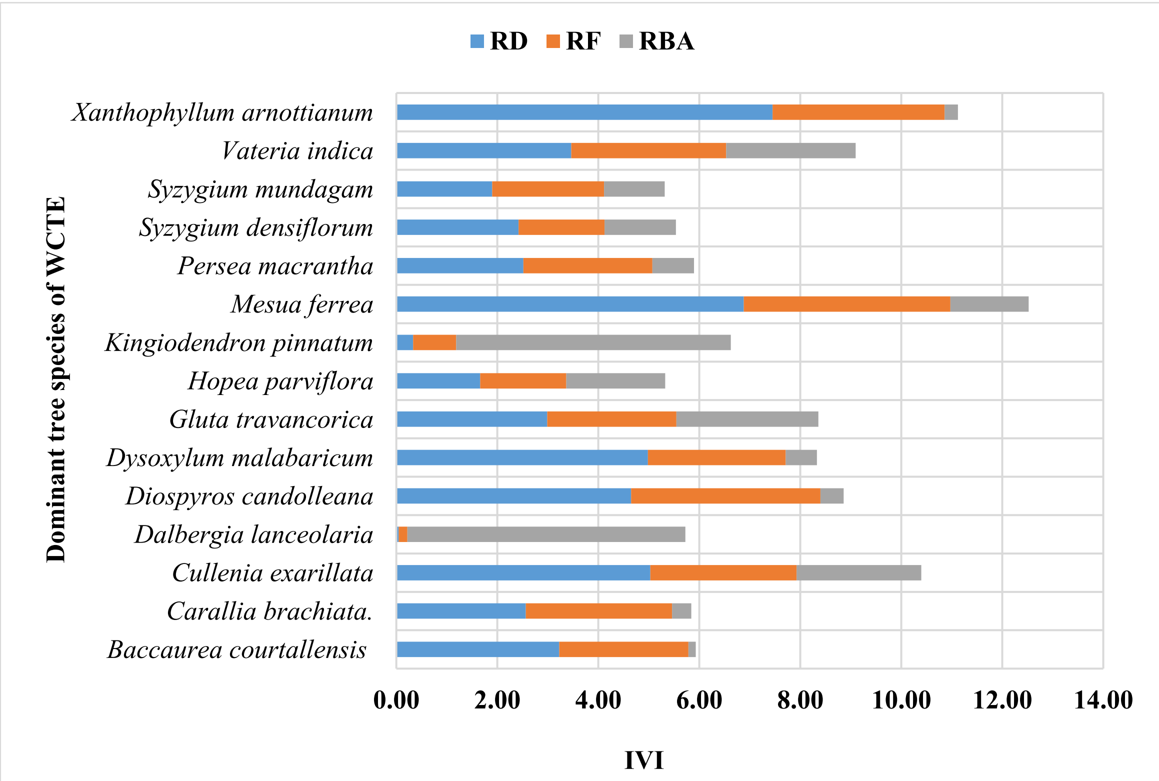


Figure 3. IVI Distribution of most dominant tree species in west coast tropical evergreen forest

Table 2. FIV value of different plant families in west coast tropical evergreen forest (WCTE)

S/No.	Family	Ds	RDs	Fs	RFs	Bas	RBA	FIV
1	Dipterocarpaceae	84.50	8.02	94.00	8.01	4.48	8.89	24.92
2	Clusiaceae	100.50	9.54	84.00	7.16	2.37	4.70	21.40
3	Myrtaceae	62.00	5.89	76.00	6.48	4.24	8.42	20.78
4	Lauraceae	75.50	7.17	102.00	8.68	1.83	3.63	19.48
5	Euphorbiaceae	76.50	7.26	92.00	7.84	1.48	2.94	18.04
6	Anacardiaceae	53.00	5.03	58.00	4.94	4.05	8.04	18.02
7	Ebenaceae	62.00	5.89	62.00	5.28	1.45	2.87	14.04
8	Fabaceae	9.50	0.90	20.00	1.70	5.59	11.08	13.69
9	Moraceae	5.00	0.47	12.00	1.02	5.81	11.53	13.02
10	Myristicaceae	32.00	3.04	54.00	4.60	2.19	4.34	11.97
11	Bombacaceae	54.00	5.13	38.00	3.24	1.68	3.33	11.70
12	Xanthophyllaceae	78.50	7.45	40.00	3.41	0.13	0.26	11.12
13	Meliaceae	56.50	5.36	46.00	3.92	0.80	1.60	10.88
14	Annonaceae	37.00	3.51	52.00	4.77	1.47	2.91	10.85
15	Sapindaceae	37.50	3.56	54.00	4.60	0.81	1.61	9.77
16	Rubiaceae	36.00	3.42	40.00	3.41	0.79	1.57	8.40
17	Rhizophoraceae	27.00	2.56	34.00	2.90	0.19	0.38	5.84
18	Celestraceae	13.50	1.28	24.00	2.05	1.04	2.07	5.39
19	Olacaceae	24.00	2.28	30.00	2.56	0.12	0.23	5.06
20	Eleocarpaceae	16.50	1.57	26.00	2.22	0.56	1.11	4.90
21	Combretaceae	5.50	0.52	8.00	0.68	1.61	3.20	4.41

S/No.	Family	Ds	RDs	Fs	RFs	Bas	RBA	FIV
22	Flacoutiaceae	5.00	0.47	10.00	0.85	1.16	2.30	3.63
23	Symplocaceae	20.00	1.90	16.00	1.36	0.13	0.26	3.52
24	Verbenaceae	1.00	0.09	4.00	0.34	1.36	2.69	3.13
25	Sapotaceae	7.50	0.71	6.00	0.51	0.67	1.33	2.56
26	Bignoniaceae	5.00	0.47	6.00	0.51	0.77	1.53	2.52
27	Icacinaceae	11.50	1.09	10.00	0.85	0.23	0.45	2.39
28	Myrsinaceae	10.00	0.95	12.00	1.02	0.12	0.24	2.21
29	Lythraceae	5.00	0.47	8.00	0.68	0.47	0.92	2.08
30	Staphyleaceae	5.00	0.47	6.00	0.51	0.49	0.98	1.97
31	Sterculiaceae	8.00	0.76	8.00	0.68	0.23	0.46	1.90
32	Burseraceae	1.50	0.14	6.00	0.51	0.47	0.92	1.58
33	Ulmaceae	4.00	0.38	8.00	0.68	0.18	0.36	1.42
34	Cornaceae	3.50	0.33	4.00	0.34	0.20	0.40	1.07
35	Achariaceae	3.50	0.33	4.00	0.34	0.16	0.32	0.99
36	Theaceae	3.50	0.33	4.00	0.34	0.13	0.26	0.94
37	Caesalpiniaceae	2.00	0.19	4.00	0.34	0.19	0.39	0.92
38	Asteraceae	1.50	0.14	4.00	0.34	0.10	0.19	0.67
39	Opiliaceae	1.00	0.09	2.00	0.17	0.20	0.40	0.66
40	Oleaceae	2.00	0.19	4.00	0.34	0.07	0.13	0.66
41	Rutaceae	1.00	0.09	4.00	0.34	0.02	0.04	0.48
42	Boraginaceae	0.50	0.05	2.00	0.17	0.13	0.25	0.47
43	Dilleniaceae	1.00	0.09	2.00	0.17	0.07	0.14	0.41
44	Melastomataceae	1.50	0.14	2.00	0.17	0.03	0.05	0.37

S/No.	Family	Ds	RDs	Fs	RFs	Bas	RBA	FIV
45	Rutaceae	1.00	0.09	2.00	0.17	0.03	0.05	0.32
46	Magnoliaceae	0.50	0.05	2.00	0.17	0.04	0.08	0.30
47	Bixaceae	0.50	0.05	2.00	0.17	0.04	0.08	0.29
48	Urticaceae	0.50	0.05	2.00	0.17	0.02	0.04	0.25

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; FIV- Family importance value of the species)

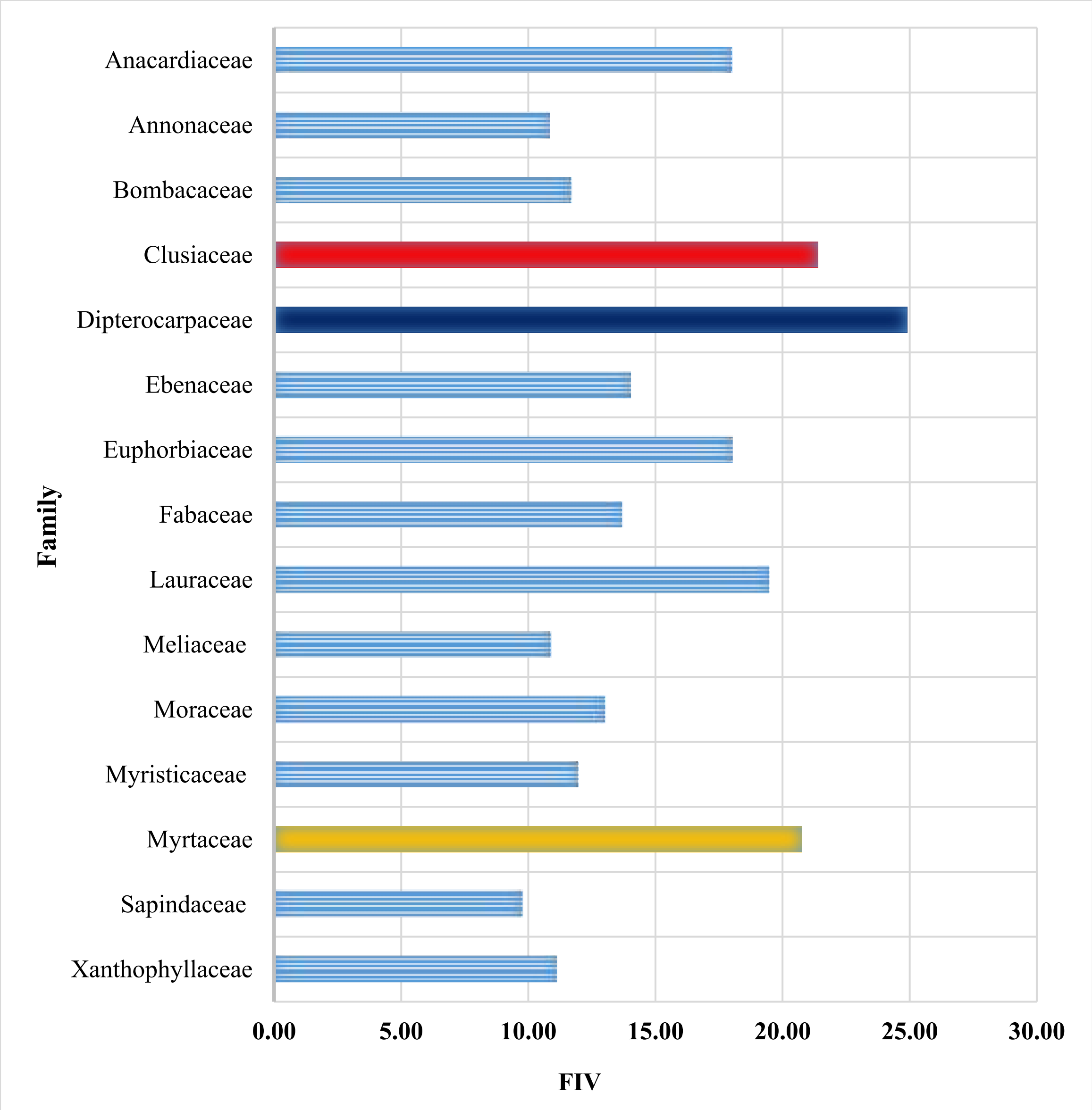


Figure 4. FIV of dominant families of tropical west coast tropical evergreen forest

4.1.1.5. Floristic diversity of tree species of west coast tropical evergreen forest

Species diversity indices for the tree species of west coast tropical evergreen forest were calculated. The Simpson index (1-D) value was 0.97, Shannon-Weiner index (H) was recorded as 4.10. The value of the Margalef index of richness was calculated as 15.42 while the equitability (J) value and evenness was found to be 0.85 and 0.49, respectively (Table 3).

Table 3. Diversity indices of tree species of tropical wet evergreen forest

Taxa_S	119
Individuals	2108
Dominance_D	0.028
Simpson _1-D	0.97
Shannon_H	4.10
Margalef	15.42
Evenness_e^H/S	0.49
Equitability_J	0.85

4.1.1.6. Ecological distance by clustering of tropical west coast tropical evergreen forest (WCTE)

Based on the similarity of the species composition, west coast tropical wet evergreen forest, the cluster analysis divided the group of 50 plots into six major groups. Plot 1, 2, 3, 4, 5, 6, 7, 8, 9 were grouped into a single cluster. Plot 13 and 14 were grouped as single clusters. Plot 15 and 16 were grouped as one cluster. Plot 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38. Plot 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, and 50 were also grouped as one cluster. The three main groups manifested the compositional similarities in relation to altitude (figure 5).

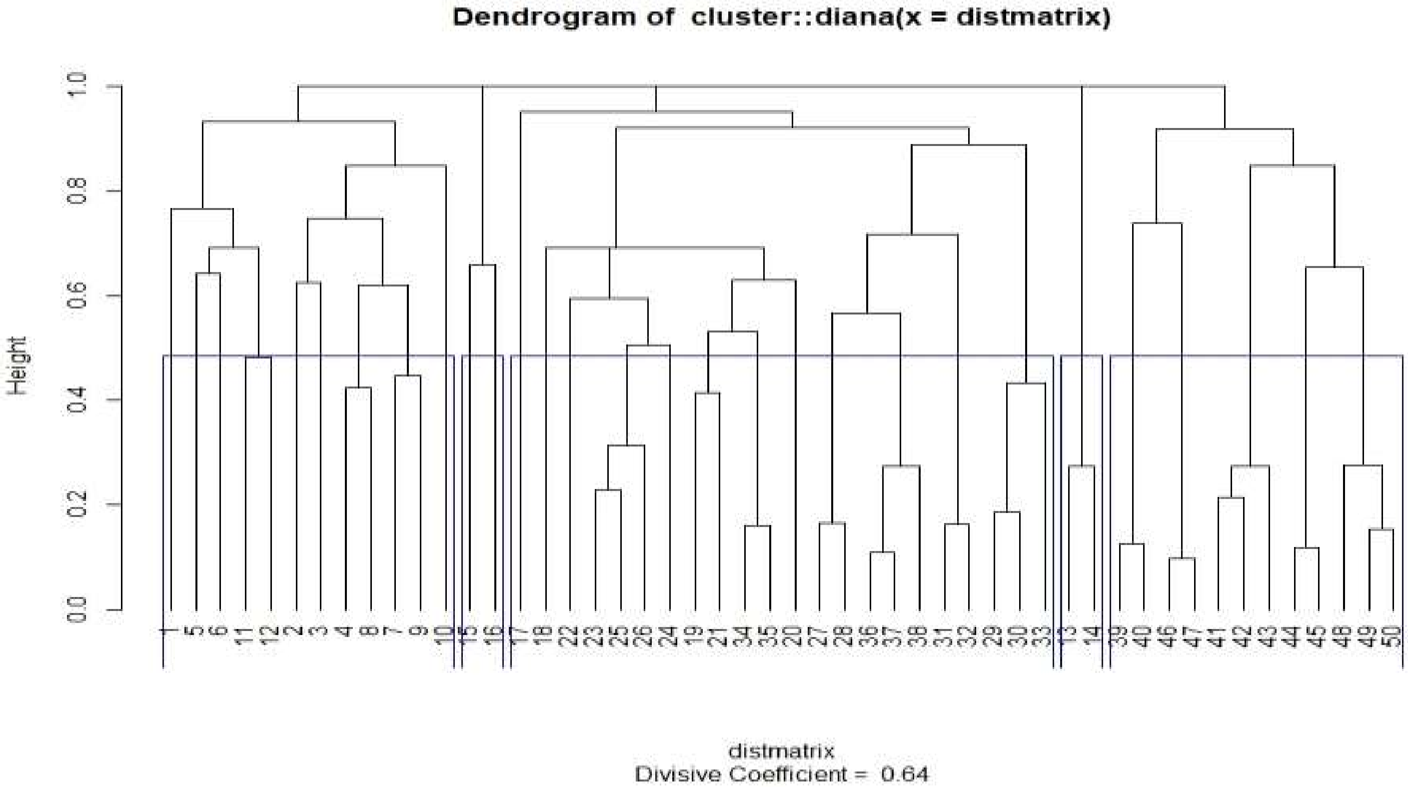


Figure 5. Cluster analysis of different plots in west coast tropical evergreen forest

4.1.1.7. Different species assemblages in west coast tropical evergreen forest

The detrended correspondence analysis (DCA) of WCTE assembled the forest into different groups. The major and recognised assocatioan are as follows: Firstly, the assemblage of group of species constituting *Diospyros candolleana*, *Mesua ferrea*, *Cullenia exarillata*, *Vateria indica*, *Xanthaphyllum arnottianum*, *Baccaurea courtallensis*, and *Dysoxylum malabaricum*. Secondly, species assemblage constituted of *Cinnamomum malabatarum*, *Glochidion zeylanicus*, *Bischofia javonica* and *Canarium strictum*. Thirdly, the species assemblage of *Mallotus philippensis*, *Myristica dactyloides*, *Pterospermum diversifolium* and *Actinodaphne malabarica* was also recognized. The forth assemblage recorded constituted of *Syzygium densiflorum*, *Symplocos cochinchinensis*, *Nothopegia celebrookiana* and *Celtis timorensis*. The fifth assemblage identified was that of *Bhesa indica*, *Measa indica* and *Elaeocarpus munronii* (figure 6).

4.1.1.8. REGENERATION STATUS OF TREES SPECIES OF WEST COAST TROPICAL EVERGREEN FOREST

4.1.1.8.1. Floristic structure of tree saplings of WCTE

In 2150 m^2 sampling area, a total of 770 individual saplings belonging to 95 different sapling species with a density of 3581.40 ha^{-1} was recorded. The highest density (D= 320.93) was recorded for *Mesua ferrea* followed by (D=241.86) *Dysoxylum malabaricum*, *Xanthaphyllum arnottianum* (D=209.30), *Diospyros candolleana* (IVI=190.70) and *Cullenia exarillata* (D=176.74) (Table 4).

4.1.1.8.1.1. Relative importance of tree saplings of west coast tropical evergreen forest

The most dominant tree saplings of WCTE is *Mesua ferrea* (IVI= 17.55), followed by *Dysoxylum malabaricum* (IVI= 10.79), *Xanthophyllum arnottianum* (IVI= 9.88), *Diospyros candolleana* (IVI= 9.62), *Cullenia exarillata* (IVI=8.22), *Carallia brachiata* (IVI= 7.19), and (IVI=7.04) for *Baccaurea courtallensis* (Table 4). Only *Mesua ferrea* and *Dysoxylum malabaricum* recorded an IVI value greater than 10.

4.1.1.8.1.2. Abundance-frequency ratio

In the west coast tropical evergreen forest, the abundance-frequency ratio of tree saplings ranges between 3.44-0.05. The maximum value (AB/F= 3.44) was recoreded for *Calophyllum polyanthum* followed by *Artocarpus hirsutus* (AB/F=2.58) and (AB/F=1.72) for *Antiaris toxicaria* and the lowest (AB/F= 0.05) value recorded for *Mesua ferrea* respectively (Table 4 and appendix II).

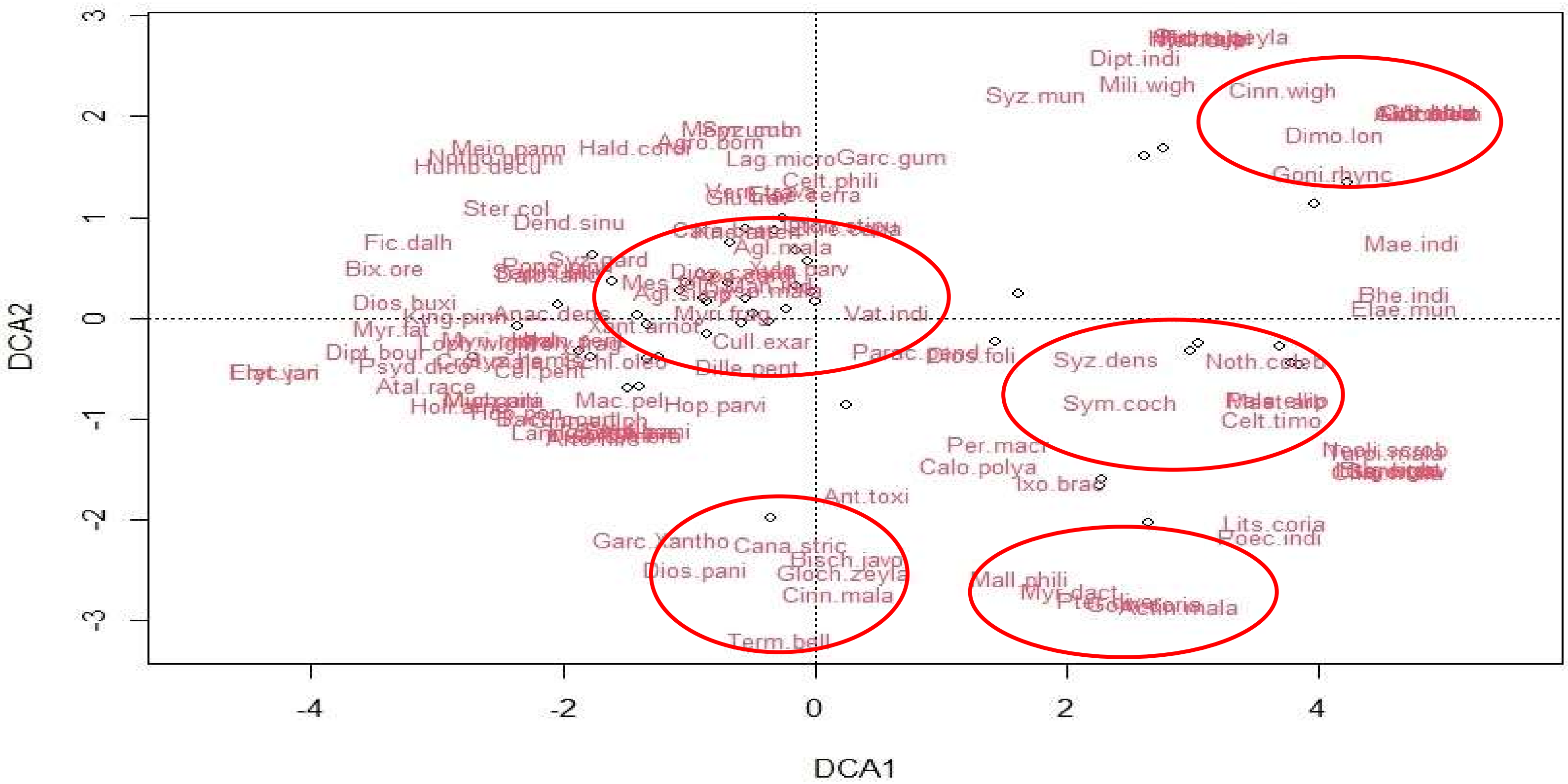


Figure 6. Detrended correspondence analysis (DCA) of different species association in west coast tropical evergreen

Table 4. The relative importance of tree saplings of west coast tropical evergreen forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Mesua ferrea*	2.03	0.05	320.93	8.96	39.53	8.59	17.55
2	*Dysoxylum malabaricum*	3.25	0.17	241.86	6.75	18.60	4.04	10.79
3	*Xanthophyllum arnottianum*	2.81	0.15	209.30	5.84	18.60	4.04	9.88
4	*Diospyros candolleana*	2.41	0.12	190.70	5.32	19.77	4.29	9.62
5	*Cullenia exarillata*	2.92	0.19	176.74	4.94	15.12	3.28	8.22
6	*Carallia brachiata*	2.67	0.19	148.84	4.16	13.95	3.03	7.19
7	*Baccaurea courtallensis*	1.93	0.12	125.58	3.51	16.28	3.54	7.04
8	*Hopea parviflora*	1.79	0.11	116.28	3.25	16.28	3.54	6.78
9	*Vateria indica*	1.77	0.12	106.98	2.99	15.12	3.28	6.27
10	*Gluta travancorica*	1.46	0.10	88.37	2.47	15.12	3.28	5.75
11	*Schleichera oleosa*	1.18	0.09	60.47	1.69	12.79	2.78	4.47
12	*Persea macrantha*	2.25	0.24	83.72	2.34	9.30	2.02	4.36
13	*Anacolosa densiflora*	1.67	0.16	69.77	1.95	10.47	2.27	4.22
14	*Cinnamomum malabatrum*	1.50	0.16	55.81	1.56	9.30	2.02	3.58
15	*Syzygium mundagam*	1.57	0.19	51.16	1.43	8.14	1.77	3.20

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

4.1.1.8.2 Floristic structure of tree seedlings of west coast tropical evergreen forest

A total of 501 individuals belonging to 85 different species with a density of 27,777 ha^{-1} was recorded in a sampling area of 180 m^2. The highest density (D=2000) was recorded for *Diospyros candolleana* followed by *Dysoxylum malabaricum* (D=1555.56), *Carallia brachiata* (D=1500), *Vateria indica* (D=1222.22), *Psydrax dicoccos* (D=1166.67), *Diospyros buxifolia* (D= 1111.11), and (D=1000) for *Mesua ferrea*, *Hopea parviflora,* and *Xanthophyllum arnottianum* respectively (Table 5).

4.1.1.8.2.1 Relative importance of tree seedlings of west coast tropical evergreen forest

The importance value index of the seedlings of different species in the west coast tropical evergreen forest was estimated. The highest (IVI=14.13) was recorded for *Diospyros candolleana* followed by *Carallia brachiata* (IVI= 9.76), (IVI= 9.44) *Dysoxylum malabaricum* (IVI= 8.74) *Vateria indica,* (IVI= 7.71) *Mesua ferrea* and *Psydrax dicoccos* (IVI= 7.53), respectively (Table 5 and figure 8).

4.1.1.8.2.2. Abundance-frequency ratio

In the west coast tropical evergreen forest, the abundance frequency ratio of tree seedlings ranges between 3.60-0.09. Five species showed the highest abundance-frequency ratio of (AB/F =3.6). The lowest (AB/F= 0.05) value was recorded for *Diospyros candolleana,* respectively. All the species showed an AB/F ratio value greater than 0.05 (Table 5 and appendix III).

Table 5. The relative importance of tree seedlings of west coast tropical evergreen forest

S/No.	Name of species	AB	AB/F	D	RD	F	RF	IVI
1	*Diospyros candolleana*	1.33	0.09	2000.00	7.19	15.00	6.94	14.13
2	*Carallia brachiata*	1.59	0.17	1500.00	5.39	9.44	4.37	9.76
3	*Dysoxylum malabaricum*	1.87	0.22	1555.56	5.59	8.33	3.86	9.44
4	*Vateria indica*	1.29	0.14	1222.22	4.39	9.44	4.37	8.76
5	*Mesua ferrea*	1.13	0.13	1000.00	3.59	8.89	4.11	7.71
6	*Psydrax dicoccos*	1.62	0.22	1166.67	4.19	7.22	3.34	7.53
7	*Hopea parviflora*	1.20	0.14	1000.00	3.59	8.33	3.86	7.45
8	*Schleichera oleosa*	1.13	0.14	944.44	3.39	8.33	3.86	7.25
9	*Xanthophyllum arnottianum*	1.29	0.17	1000.00	3.59	7.78	3.60	7.19
10	*Diospyros buxifolia*	2.00	0.36	1111.11	3.99	5.56	2.57	6.56
11	*Cullenia exarillata*	1.33	0.20	888.89	3.19	6.67	3.08	6.28
12	*Holigarna arnottiana*	1.70	0.31	944.44	3.39	5.56	2.57	5.96
13	*Baccaurea courtallensis*	1.17	0.18	777.78	2.79	6.67	3.08	5.88
14	*Persea macrantha*	1.00	0.16	611.11	2.20	6.11	2.83	5.02
15	*Gluta travancorica*	1.20	0.22	666.67	2.40	5.56	2.57	4.97

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

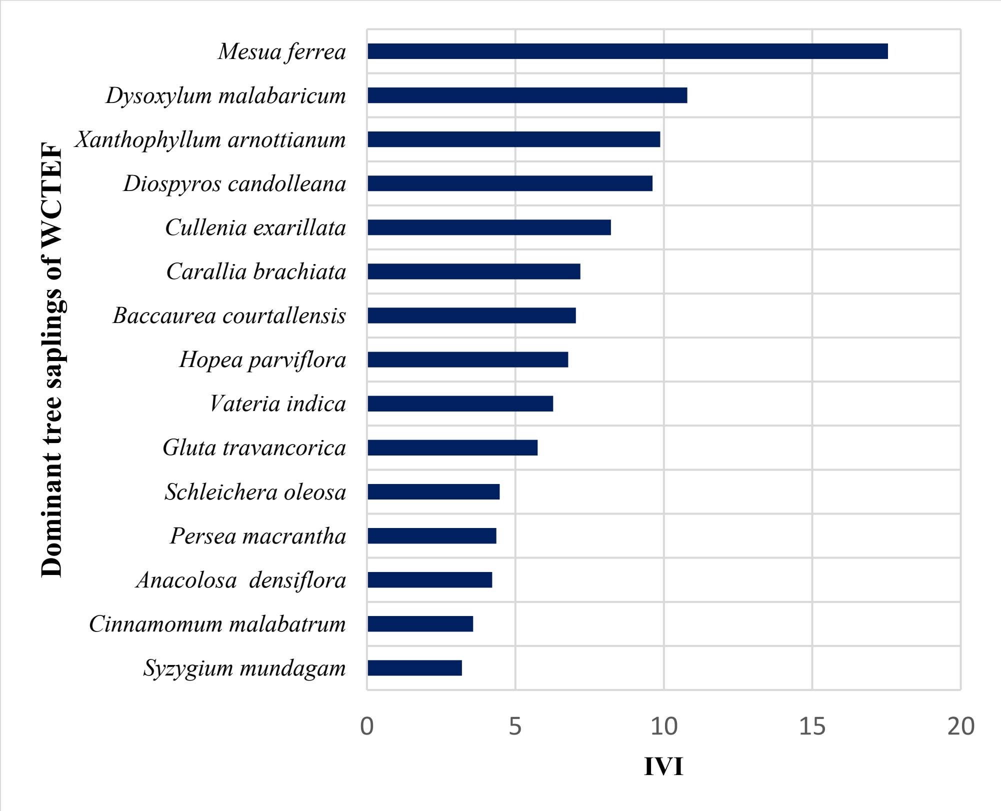


Figure 7. The IVI value of the most dominant tree saplings of west coast tropical evergreen forest

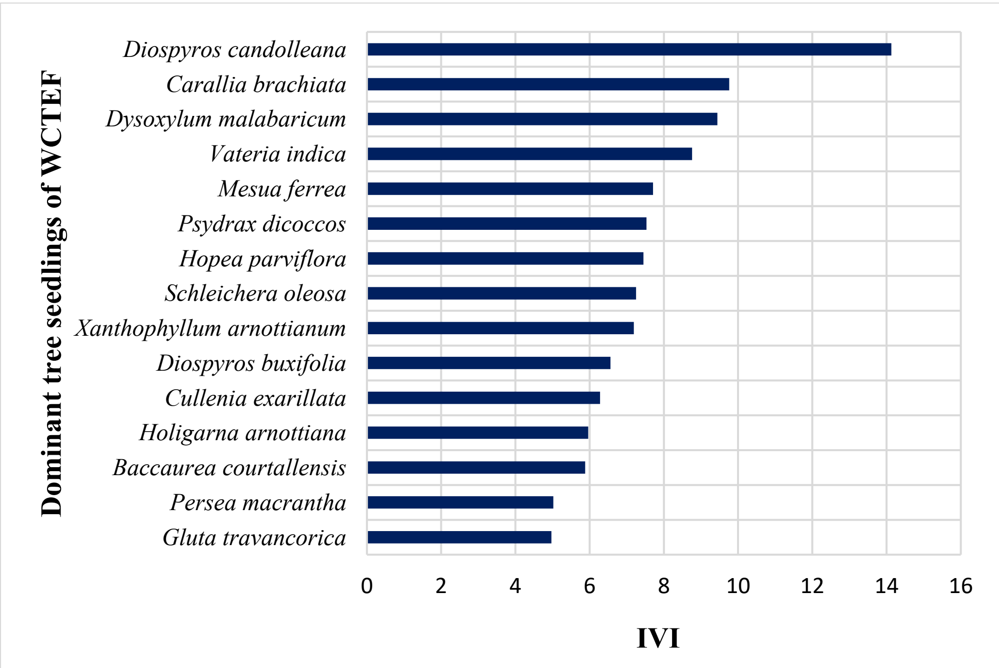


Figure 8. The IVI value of the most dominant tree seedlings of west coast tropical evergreen forest

4.1.1.8.3. Diversity indices of tree saplings and seedlings of west coast evergreen forest

Different diversity indices of the regenerating species of the tropical wet evergreen forest (WCTE) was calculated. The species dominance (D) was recorded at 0.032 for tree saplings and 0.029 for tree seedlings, the Simpson index (1-D) was recorded for the tree saplings (0.96) and the tree seedlings (0.97). The Shannon-Weiners index (H) was recorded 3.92 for tree saplings and (3.88) tree seedlings. The Margalef index for tree saplings was estimated as 14.14 and 13.54 for tree seedlings, while species evenness (e^H/S) and equitability (J) was recorded (0.53 and 0.86) for tree saplings and (0.52 and 0.86) for tree seedlings, respectively (Table 6 and figure 9).

Table 6. Different diversity indices for the tree saplings and seedlings of west coast tropical evergreen forests.

Diversity Indices	Saplings	Seedlings
Taxa_S	95	85
Individuals	770	501
Dominance_D	0.032	0.029
Simpson _1-D	0.97	0.97
Shannon_H	3.92	3.88
Margalef	14.14	13.51
Evenness_e^H/S	0.53	0.57
Equitability_J	0.86	0.87

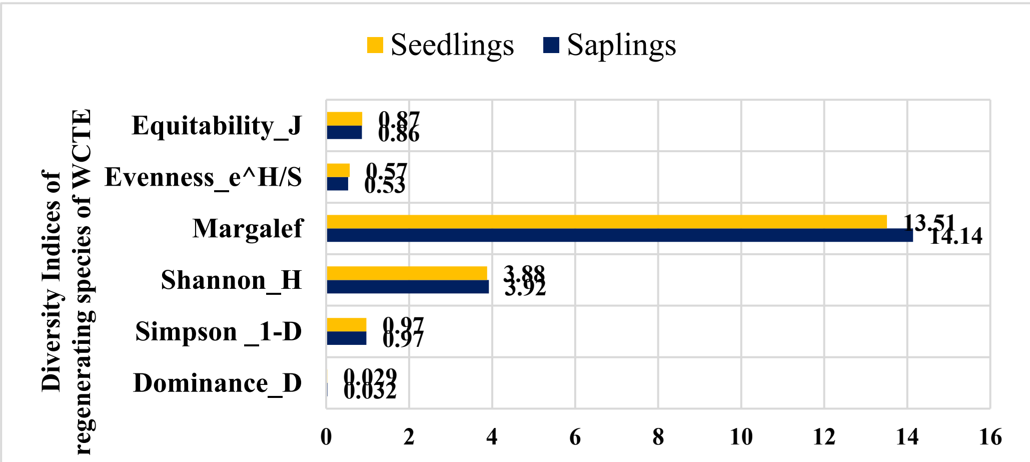


Figure 9. Diversity indices of tree saplings and seedlings of west coast tropical evergreen forest

4.1.2. Spatial structure of tree community in west coast tropical semi-evergreen forest

The tropical semi-evergreen forest constitutes the second most dominant vegetation in Shendurney wildlife Sanctuary. The result of its enumeration revealed a total of 101 species belonging to 84 genera and 38 families and a density of 914.55 individuals ha^1 from the sampling area of 22,000 m^2. Twenty-six species are endemic to Western Ghats, representing 24.75 %, nine species are endemic to Southern Western Ghats, representing 9.90 %. However, with respect to threatened categories one species is critically endangered (CE), nine species are endangered (EN), fourteen species are in the least concern category (LC), two species are near threatened (NT), and seven species are vulnerable to extinction in near future (Appendix XVIII).

4.1.2.1. Girth class distribution

The girth class distribution for tree species with a girth ≥ 10 cm in the tropical semi-evergreen forest was estimated (Figure 10). The distribution of the trees showed L shaped distribution as showed decreasing density with increasing girth size. The girth class (10-30 cm) occupied the greater number (814 species), representing 40.50% of individuals tree species while the lowest number (46 species) of individuals species was recorded in the 181-210 girth class distribution.

4.1.2.2. Relative importance of species in WCTSE

The dominant species in the WCTSE are *Baccaurea courtallensis* (IVI=10.78), *Hopea parviflora* (IVI=10.03), *Xanthaphyllum arnottianum* (IVI= 9.05), *Kingiodendron pinnatum* (IVI= 7.08), *Schleichera oleosa* (IVI= 6.92), and *Dipterocarpus indicus* (IVI= 6.64) (Table 7 and figure 11). The higher importance value index for *Baccaurea courtallensis, Xanthaphyllum arnottianum* is attributed with its relative density and frequency; for *Bombax ceiba* and *Artocarpus hirsatus,* the higher IVI is associated with a relative basal area of species (Table 7 and figure 11).

4.1.2.3. Abundance-frequency ratio

The abundance-frequency ratio of tree species in WCTSE ranges between 2.20-0.04. The highest value (AB/F=2.20) was recorded for *Diospyros candolleana* followed by (AB/F=1.65) for *Buchanania lanceolata* and *Celtis philippensis*. The lowest value (AB/F=0.04) was recorded for *Schleichera oleosa* and *Kingiodendron pinnatum*. Only two species showed AB/F less than 0.05 (Table 7).

4.1.2.4. Relative importance of families of west coast semi-evergreen forest

In the tropical semi-evergreen forest, the dominant families are Euphobiaceae (FIV=31.68), Dipterocarpaceae (FIV=24.18), Rubiaceae (FIV=18.99), Ebenaceae (FIV=17.16), Malvaceae (FIV= 16.43), Sapindaceae (FIV=16.09), Moraceae (FIV= 12.98), and Anacardiaceac (FIV=10.42). The lowest family importance index (FIV=0.37) were recorded for Cannabaceae, represented by only one specie (Table 8 and figure 12).

Table 7. IVI values of different species in west coast tropical semi-evergreen (WCTSE)

S/No.	Name of Species	AB	AB/F	D	RD	Fs	RFs	BA	RBAs	IVI
1	*Baccaurea courtallensis*	4.33	0.08	59.09	6.46	54.55	4.03	1.22	0.29	10.78
2	*Hopea parviflora*	3.29	0.08	35.91	3.93	43.64	3.22	12.09	2.88	10.03
3	*Xanthophyllum arnottianum*	6.63	0.19	57.27	6.26	34.55	2.55	2.87	0.68	9.50
4	*Kingiodendron pinnatum*	1.71	0.04	16.36	1.79	38.18	2.82	10.37	2.47	7.08
5	*Schleichera oleosa*	2.04	0.04	25.00	2.73	49.09	3.62	2.37	0.57	6.92
6	*Dipterocarpus indicus*	1.25	0.06	6.82	0.75	21.82	1.61	18.00	4.29	6.64
7	*Stereospermum colais*	3.00	0.08	28.64	3.13	38.18	2.82	2.46	0.58	6.53
8	*Dysoxylum malabaricum*	2.56	0.08	20.91	2.29	32.73	2.42	5.35	1.27	5.98
9	*Polyalthia fragrans*	2.53	0.07	21.82	2.39	34.55	2.55	4.10	0.98	5.91
10	*Tetrameles nudiflora*	1.46	0.06	8.64	0.94	23.64	1.74	12.82	3.05	5.74
11	*Bombax ceiba*	1.00	0.11	2.27	0.25	9.09	0.67	20.16	4.80	5.72
12	*Aporusa cardiosperma*	9.33	0.57	38.18	4.17	16.36	1.21	0.94	0.22	5.61
13	*Artocarpus hirsutus*	1.50	0.08	6.82	0.75	18.18	1.34	14.33	3.41	5.50
14	*Cinnamomum malabatrum*	2.78	0.08	22.73	2.49	32.73	2.42	1.59	0.38	5.28
15	*Diospyros buxiflora*	3.21	0.13	20.45	2.24	25.45	1.88	4.52	1.08	5.19

(AB- Abundance ; Species density; RDs – Relative density of the species; Fs- Frequency of the species ; RFs- Relative frequency of the species; BAs- Basal area of the species ; RBA – Relative basal area of the species ; IVI- Importance value index of the species)

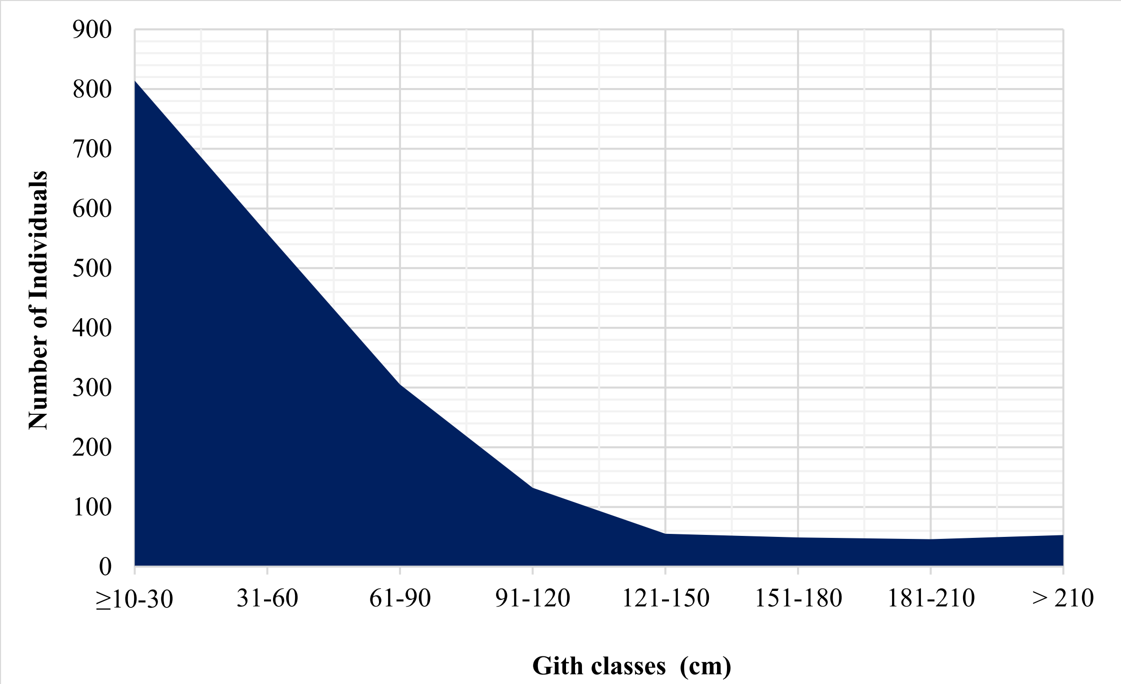


Figure 10. The girth class distribution of tree species of west coast tropical semi-evergreen forest

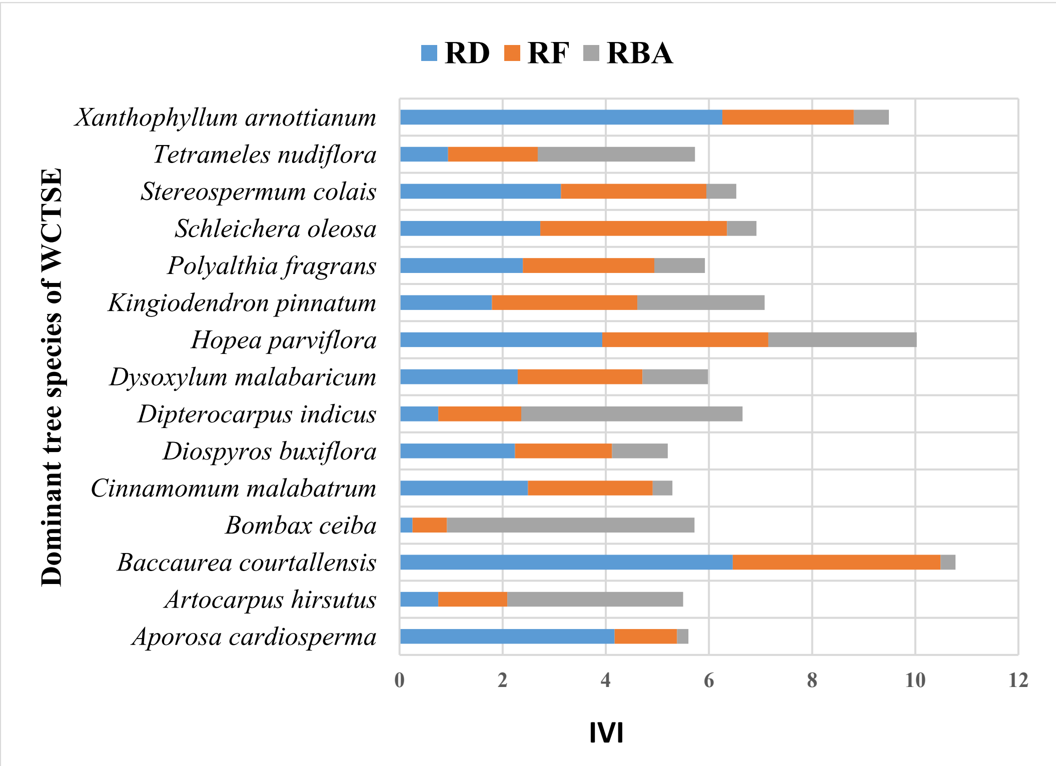


Figure 11. IVI distribution of most dominant tree species of tropical semi-evergreen forest

Table 8. FIV values of different plants families of tropical semi-evergreen forest

S/No.	Family	D	RD	Fs	RFs	BA	RBAs	IVI
1	Euphorbiaceae	143.64	15.71	161.82	11.95	17.80	4.03	31.68
2	Dipterocarpaceae	56.82	6.21	100.00	7.38	46.77	10.58	24.18
3	Rubiaceae	57.27	6.26	60.00	4.43	36.69	8.30	18.99
4	Ebenaceae	76.82	8.40	89.09	6.58	9.65	2.18	17.16
5	Malvaceae	23.18	2.53	43.64	3.22	47.18	10.68	16.43
6	Sapindaceae	39.55	4.32	80.00	5.91	25.92	5.86	16.09
7	Moraceae	12.27	1.34	34.55	2.55	40.14	9.08	12.98
8	Anacardiaceae	15.00	1.64	36.36	2.68	26.96	6.10	10.42
9	Bignoniaceae	41.82	4.57	52.73	3.89	7.02	1.59	10.05
10	Meliaceae	30.91	3.38	49.09	3.62	12.23	2.77	9.77
11	Annonaceae	25.45	2.78	45.45	3.36	15.70	3.55	9.69
12	Xanthophyllaceae	57.27	6.26	34.55	2.55	2.87	0.65	9.46
13	Clusiaceae	25.00	2.73	54.55	4.03	11.71	2.65	9.41
14	Myrtaceae	10.91	1.19	29.09	2.15	23.39	5.29	8.63
15	Fabaceae	18.64	2.04	45.45	3.36	12.92	2.92	8.32
16	Lauraceae	31.82	3.48	43.64	3.22	7.01	1.59	8.29
17	Combretaceae	22.27	2.44	29.09	2.15	8.28	1.87	6.46
18	Apocynaceae	25.00	2.73	32.73	2.42	3.72	0.84	5.99
19	Datiscaceae	8.64	0.94	23.64	1.74	13.03	2.95	5.64
20	Lamiaceae	15.45	1.69	32.73	2.42	5.84	1.32	5.43
21	Myristicaceae	10.91	1.19	18.18	1.34	12.50	2.83	5.36
22	Oleoceae	21.36	2.34	27.27	2.01	2.98	0.67	5.02
23	Celestraceae	8.18	0.89	14.55	1.07	12.55	2.84	4.81

S/No.	Family	D	RD	Fs	RFs	BA	RBAs	IVI
24	Burseraceae	13.18	1.44	30.91	2.28	3.23	0.73	4.45
25	Salicaceae	17.73	1.94	21.82	1.61	1.69	0.38	3.93
26	Achariaceae	12.27	1.34	25.45	1.88	3.05	0.69	3.91
27	Aptandraceae	7.73	0.84	20.00	1.48	4.42	1.00	3.32
28	Lythraceae	8.64	0.94	14.55	1.07	5.57	1.26	3.28
29	Rutaceae	15.91	1.74	16.36	1.21	1.04	0.24	3.18
30	Sapotaceae	12.27	1.34	14.55	1.07	2.96	0.67	3.08
31	Melastomataceae	12.27	1.34	14.55	1.07	0.96	0.22	2.63
32	Strombosiaceae	7.27	0.80	12.73	0.94	3.37	0.76	2.50
33	Rhizophoraceae	7.73	0.84	10.91	0.81	1.75	0.40	2.05
34	Cornaceae	5.00	0.55	7.27	0.54	3.95	0.89	1.98
35	Loganiaceae	6.82	0.75	9.09	0.67	2.25	0.51	1.92
36	Elaeocarpaceae	6.36	0.70	10.91	0.81	1.64	0.37	1.87
37	Dilleniaceae	1.82	0.20	5.45	0.40	2.80	0.63	1.24
38	Cannabaceae	1.36	0.15	1.82	0.13	0.40	0.09	0.37

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; FIV- Family importance value of the species)

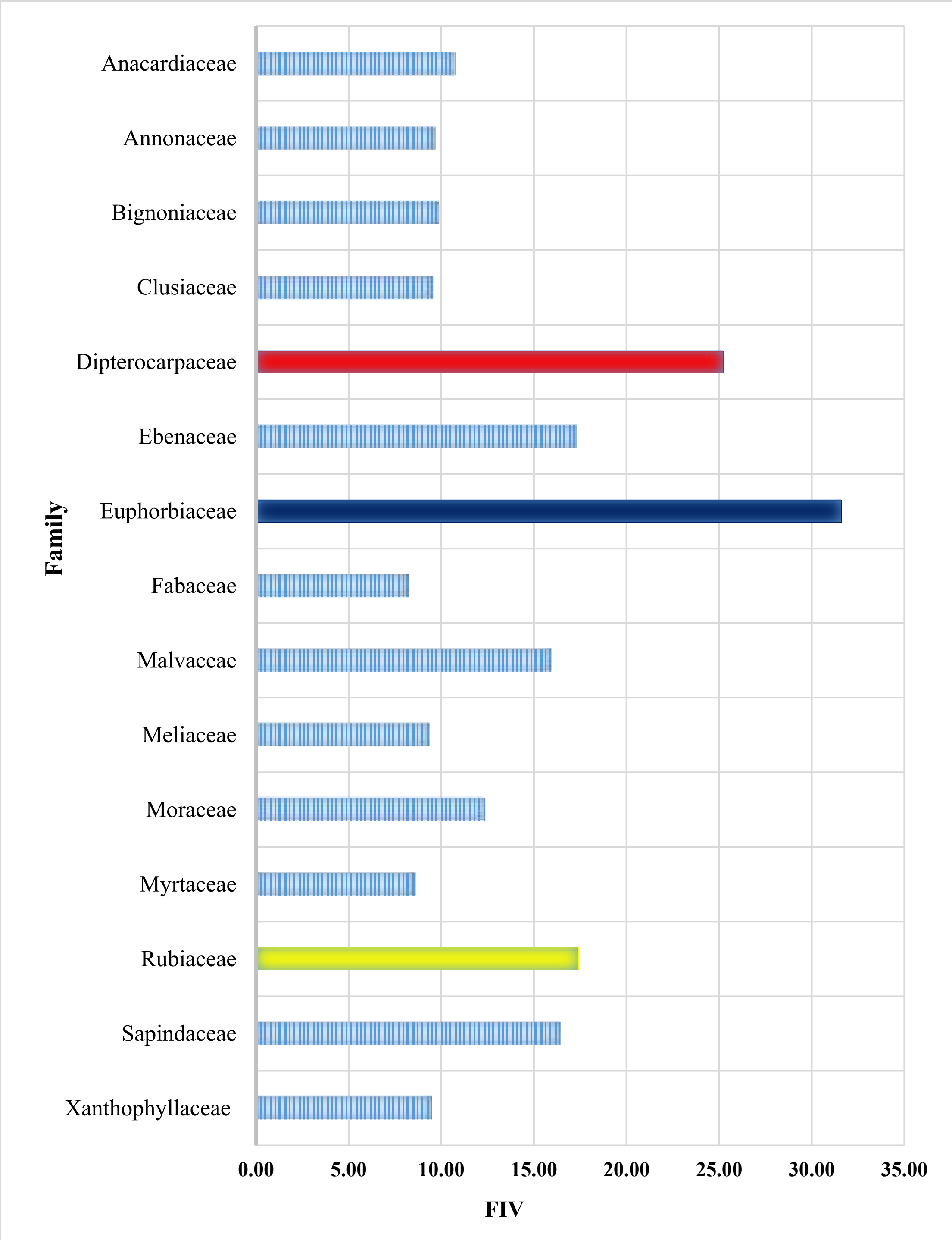


Figure 12. FIV of dominant families of tree species in west coast tropical semi-evergreen forest

4.1.2.5. Floristic diversity of tree species in west coast tropical semi-evergreen forest

Different diversity indices were calculated for the tree species of west coast tropical semi-evergreen forest. The dominance (D) was estimated as 0.024, Simpson index (1-D) was estimated as 0.97, for the Shannon-Weiner index (H), the value was calculated as (4.09) while for Margalef, Evenness (e^H/S), and Equitability index (J), the value were estimated as 13.15, 0.598 and 0.888 respectively (Table 9).

Table 9. Different diversity indices of Tropical semi evergreen forest (WCTSE)

Taxa_S	101
Individuals	2012
Dominance_D	0.024
Simpson _1-D	0.97
Shannon_H	4.09
Margalef	13.15
Evenness_e^H/S	0.60
Equitability_J	0.89

4.1.2.6. Ecological distance by clustering of west coast tropical semi-evergreen forest

In the tropical semi-evergreen forest the cluster analysis classified the ecosystem into five groups based on the compositional similarities. Plot 1, 2, 3, 8, 9, 10, 14, 15, 17, 36, 37, 47, 48, 49, 50, 51 and 52 in one cluster. Plot 5, 6, 7, 11, 20, 20, 22, 24, 25, 26, 27, 28, 29, 30, 32, 38 and 39 in one cluster. Plot 12, 13, 16, 18 in one cluster. Plot 4, 41, 42, 43, 45, 46 and 54 in one cluster. Plot 19, 33, 34, 35, 53 and 55 in another cluster (Figure 13).

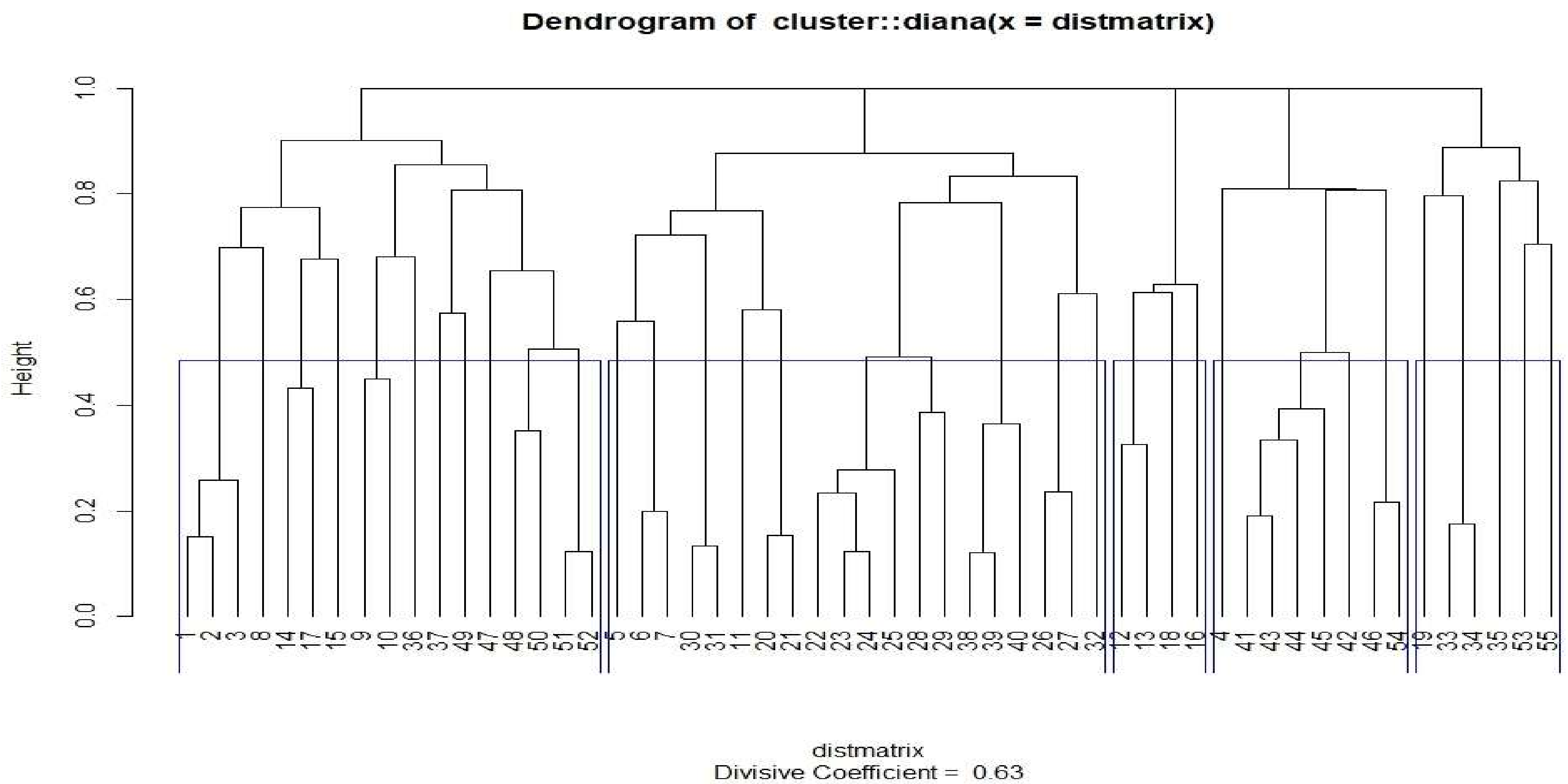


Figure 13. Cluster analysis of different plots of west coast tropical semi-evergreen forest

4.1.2.7. Different species assemblages in west coast tropical semi-evergreen forest

The detrended correspondence analysis of WCTSE identified the assemblage of different species such as *Ixora brachiata, Tabernaemontana alternifolia*, *Aporosa cardiosperma*, *Diospyros candolleana, Artocarpus hirsutus, Lagerstroemia microcarpa, Litsea coriacea, Grewia tillifolia* are grouped as one assemblage. The second assemblage identified was that of *Chionanthus mala-elengi, Sapindus laurifolius, Pterospermum diversifolium, Dimocarpus longan, Antiaris toxicaria,* and *Strychnos-nux-vomica*. The third assemblage identified was for *Bischofia javanica, Diospyros buxiflora,* and *Syzygium gardneri*. The fourth assemblage identified was that of *Buchanania lanceolata*, *Knema attenuata*, *Terminalia paniculata, Psydrax dioccos, Kingiodendron pinnatum,* and *Anacolosa densiflora*. The sixth assemblages was for *Diospyros montana, Olea dioica, Dysoxylum malabaricum, Pajanelia longifolia, Sterculia guttata,* and *Gmelina arborea* (figure 14).

4.1.2.8. REGENERATION STATUS OF TREES SPECIES OF WEST COAST TROPICAL SEMI-EVERGREEN FOREST

4.1.2.8.1. Floristic structure of tree saplings of west coast semi-evergreen forest

In 2350 m^2 sampling area, a total of 689 individual saplings consisting of 85 different species with a density of 2931.91 ha^1 was recorded. The highest density (D=251.06) was recorded for *Xanthaphyllum arnottianum* followed by *Hopea parviflora* (D=234.04), *Cinnamomun malabatrum* (D= 170.21), *Baccaurea courtallensis* (D=140.43), *Diospyros buxifolia* (D= 106.38), and *Anacolosa densiflora* (D=89.36) (Table 10).

4.1.2.8.1.1. Relative importance of tree saplings of semi-evergreen forest

The dominant species are *Xanthaphyllum arnottianum* (IVI=15.04) followed by *Hopea parviflora* (IVI= 13.95), *Cinnamomun malabatrum* (IVI=11.25) and *Baccaurea courtallensis* (IVI=10.49), *Diospyros buxifolia* (IVI=7.77), *Anacolosa densiflora* (IVI=5.90), and *Ixora brachiata* (IVI=5.03) (Table 10 and figure 15).

4.1.2.8.1.2 Abundance–frequency ratio

The abundance-frequency ratio of the tree saplings of west coast tropical semi-evergreen forest ranged between 2.58-0.07. The highest AB/F ratio (AB/F= 2.58) was recorded for *Sageraea grandiflora* while the lowest value (AB/F=0.06) was recorded for *Baccaurea courtallensis*. All the species showed the value of AB/F greater than 0.05 (Table 10 and appendix V).

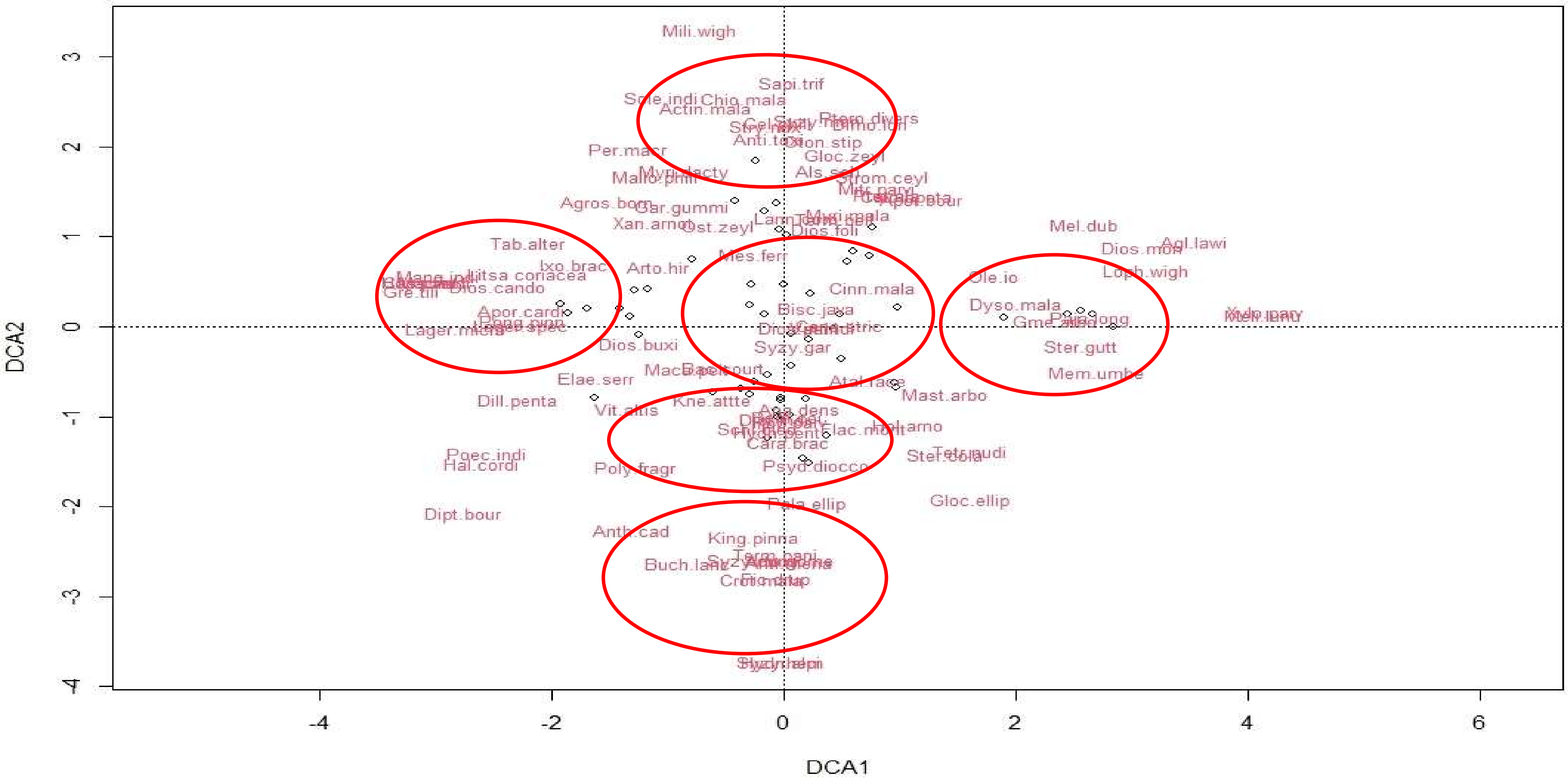


Figure 14. Detrended correspondence analysis (DCA) of different species association in west coast tropical semi-evergreen forest

Table 10. IVI of the dominant tree saplings of west coast tropical semi-evergreen (WCTSE)

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Xanthophyllum arnottianum*	2.36	0.09	251.06	8.56	26.60	6.48	15.04
2	*Hopea parviflora*	2.39	0.10	234.04	7.98	24.47	5.96	13.94
3	*Cinnamomum malabatrum*	1.90	0.09	170.21	5.81	22.34	5.44	11.25
4	*Baccaurea courtallensis*	1.50	0.06	140.43	4.79	23.40	5.70	10.49
5	*Diospyros buxifolia*	1.56	0.09	106.38	3.63	17.02	4.15	7.77
6	*Anacolosa densiflora*	1.91	0.16	89.36	3.05	11.70	2.85	5.90
7	*Ixora brachiata*	1.36	0.12	63.83	2.18	11.70	2.85	5.03
8	*Mallotus philippensis*	1.50	0.14	63.83	2.18	10.64	2.59	4.77
9	*Aporosa cardiosperma*	2.25	0.26	76.60	2.61	8.51	2.07	4.69
10	*Diospyros paniculata*	2.00	0.27	59.57	2.03	7.45	1.81	3.85
11	*Dysoxylum malabaricum*	2.33	0.37	59.57	2.03	6.38	1.55	3.59
12	*Diospyros candolleana*	1.57	0.21	46.81	1.60	7.45	1.81	3.41
13	*Agrostistachys borneensis*	1.29	0.17	38.30	1.31	7.45	1.81	3.12
14	*Myristica dactyloides*	2.40	0.45	51.06	1.74	5.32	1.30	3.04
15	*Olea dioica*	2.40	0.45	51.06	1.74	5.32	1.30	3.04

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; IVI- Importance value index of the species)

4.1.2.8.2. Floristic structure of tree seedlings of west coast semi-evergreen forest

A total of 433 individuals belonging to 74 different species with density 25833.33 ha^1 was recorded in a sampling area of 168 m^2. The dominant species are *Cinnamomum malabatrum* (D=2440.48) followed by *Hopea parviflora* (D=2202.38), *Xanthaphyllum arnottianum* (D= 1785.71), *Baccaurea courtallensis* (D=1488.10), and *Diosypros buxifolia* (D= 1130.95) (Table 11 and figure 16).

4.1.2.8.2.1. Relative importance of seedlings species of west coast semi-evergreen forest

The dominant species are *Cinnamomum malabatrum* (IVI=18.03) followed by (IVI=15.92) for *Hopea parviflora*, *Xanthaphyllum arnottianum* (IVI=13.13*),* *Baccaurea courtallensis* (IVI=11.09) and *Diospyros buxifolia* (IVI= 8.82). The IVI greater than 10 was recorded only for four species (Table 11 and figure 16).

4.1.2.8.2.2. Abundance Frequency Ratio

The value of the abundance-frequency ratio of the tree seedlings of the tropical semi-evergreen forest ranged between 3.36-0.08. The highest value (AB/F=3.36) was recorded for *Alstonia scholaris*, *Croton malabaricus* and *Syzygium cumini*. The lowest (AB/F=0.08) was recorded for *Cinnamomum malabatrum*. All the species showed an AB/F ratio greater than 0.05 (Table 11 and appendix VI).

Table 11. IVI of the dominant tree seedlings of west coast tropical semi-evergreen (WCTSE)

S/No.	Names of the Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Cinnamomum malabatrum*	1.41	0.08	2440.48	9.45	17.26	8.58	18.03
2	*Hopea parviflora*	1.48	0.10	2202.38	8.53	14.88	7.40	15.92
3	*Xanthophyllum arnottianum*	1.43	0.11	1785.71	6.91	12.50	6.21	13.13
4	*Baccaurea courtallensis*	1.39	0.13	1488.10	5.76	10.71	5.33	11.09
5	*Diospyros buxiflora*	1.27	0.14	1130.95	4.38	8.93	4.44	8.82
6	*Ixora brachiata*	1.07	0.12	952.38	3.69	8.93	4.44	8.12
7	*Anacolosa densiflora*	1.60	0.27	952.38	3.69	5.95	2.96	6.65
8	*Aporosa cardiosperma*	2.17	0.61	773.81	3.00	3.57	1.78	4.77
9	*Schleichera oleosa*	1.00	0.21	476.19	1.84	4.76	2.37	4.21
10	*Tabernaemontana alternifolia*	1.00	0.21	476.19	1.84	4.76	2.37	4.21
11	*Hopea ponga*	1.14	0.27	476.19	1.84	4.17	2.07	3.91
12	*Dipterocarpus indicus*	1.00	0.24	416.67	1.61	4.17	2.07	3.68
13	*Vateria indica*	1.17	0.33	416.67	1.61	3.57	1.78	3.39
14	*Diospyros foliosa*	1.60	0.54	476.19	1.84	2.98	1.48	3.32
15	*Knema attenuata*	1.60	0.54	476.19	1.84	2.98	1.48	3.32

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

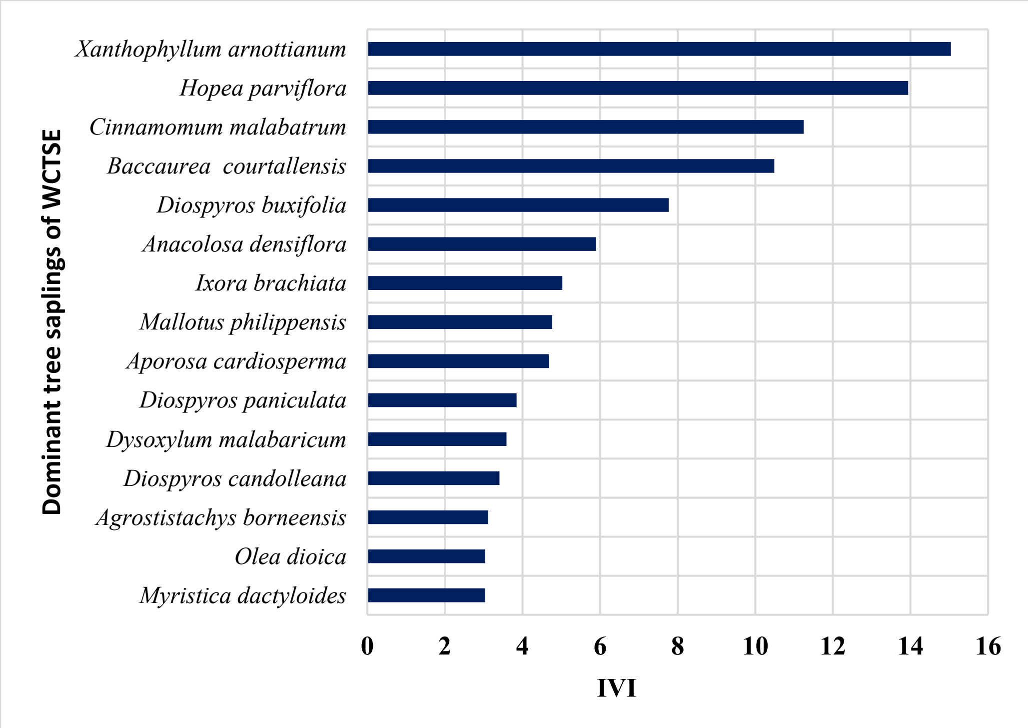


Figure 15. IVI of the dominant tree saplings of west coast tropical semi-evergreen forest

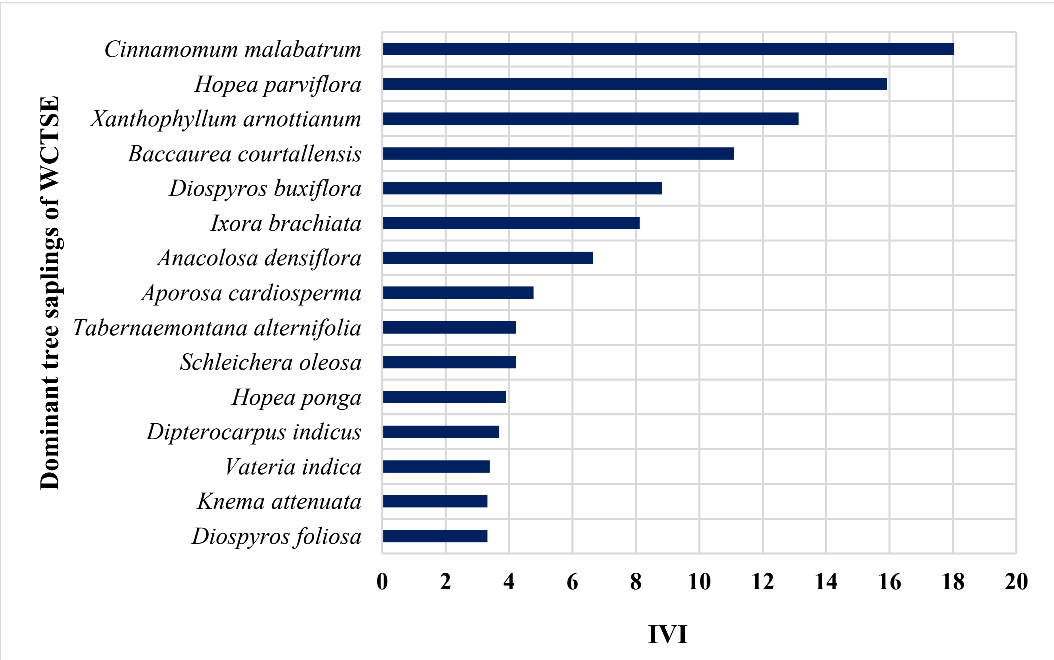


Figure 16. IVI of the dominant tree seedlings of west coast tropical semi-evergreen forest

4.1.2.8.3. Diversity indices of tree saplings and seedlings of west coast semi-evergreen forest

Different diversity indices for the regenerating species were calculated. The species dominance (D) value was recorded at 0.032 for tree saplings and 0.035 for tree seedlings. For the Simpson index (1-D), 0.97 was recorded for the tree saplings and 0.96 for the tree seedlings. The Shannon-weiners index (H) was recorded (3.92) for tree saplings and (3.82) tree seedlings. The Margalef value for tree saplings was estimated as (14.14) and 13.54 for tree seedlings, while species evenness (_e^H/S) and equitability (J) was recorded (0.53 and 0.861) for tree saplings and (0.52 and 0.861) for tree seedlings (Table 12 and figure 17).

Table 12. Diversity indices of tree saplings and seedlings in tropical semi-evergreen forest

Diversity Indices	Saplings	Seedlings
Taxa_S	85	74
Individuals	689	434
Dominance_D	0.029	0.036
Simpson _1-D	0.97	0.96
Shannon_H	3.96	3.78
Margalef	12.85	12.02
Evenness_e^H/S	0.62	0.58
Equitability_J	0.89	0.88

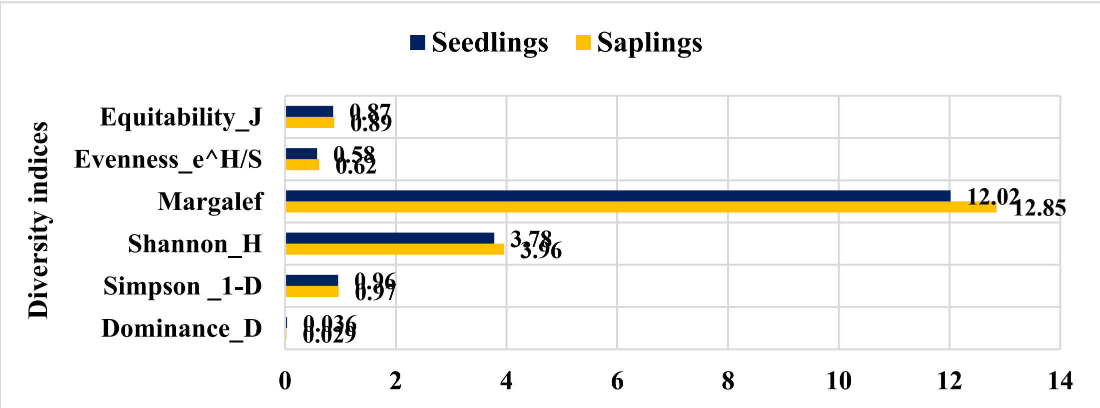


Figure 17. Diversity indices of seedlings and saplings of tropical semi-evergreen forest

4.1.3. Spatial structure of tree community southern secondary moist deciduous forest

In the southern secondary moist deciduous forest, 58 species belonging to 48 genera and 25 families and a density of 876.97 individuals ha^{-1} in a sampling area of 15,200 m^2. Out of the 58 species, five species representing 16.95 % are endemic. With respect to threatened categories, two species are endangered (EN), eight species are in the least concern category (LC), two species are near threatened (NT) and four species are vulnerable to extinction in the near future (VU). The detailed list of species from this ecosystem are given in (Appendix XIX).

4.1.3.1. Girth class distribution

The girth class distribution of the southern secondary moist deciduous forest was recorded for trees with a girth ≥ 10 cm (Figure 18). The distribution of the trees showed a completely L-shaped distribution with decreasing density with increasing girth size. The lower girth class (10-30 cm) occupied the greater number (574 species), representing 43.10 % of all individual trees. The lowest number (15 species) of individual species representing 1.1%, was recorded in the >210 girth class distribution.

4.1.3.2. Relative importance of tree species of southern secondary moist deciduous forest

The most dominant species in the tropical moist deciduous forest are *Terminalia paniculata* (IVI= 26.67) followed by *Aporosa cardiosperma* (IVI= 26.08), *Olea dioica* (IVI= 12.67) *Bombax ceiba* (IVI= 10.70) and *Tabernaemontana alternifolia* (IVI= 10.48; D= 51.26). The lowest (IVI= 0.80) was recorded for *Elaeocarpus serratus*. The higher IVI value of *Terminalia paniculata* is attributed to species relative basal area, density, and frequency. For *Aporosa cardiosperma* and *Tabernaemontana alternifolia* is attributed to species relative density and frequency, while for *Bombox ceiba*, *Bombax insigne*, and *Terminalia elliptica* the higher value is attributed to species relative density of IVI is contributed by species' relative basal area (Table 13 and figure 19).

4.1.3.3. Abundance-frequency ratio

In the southern secondary moist deciduous forest, the value of abundance-frequency ratio ranges between 2.28-0.04, except for *Schleichera oleosa* with AB/F of 0.04, all the other species have an AB/F greater than 0.05. The higher AB/F was recorded for *Pongamia pinnata* (AB/F =2.28) followed by *Melicope-lunu-ankenda* (AB/F=1.14), *Litsea coriacea* (AB/F= 0.57) and *Hymennodictyon obatum* (AB/F= 0.55) (Table 13 and appendix VII).

4.1.3.4. Relative importance of families of southern secondary moist deciduous forest

The dominant families in the southern secondary moist deciduous forest are Euphorbiaceae (FIV=52.99), Combretaceae (FIV= 41.23), Malvaceae (FIV= 32.73), Apocynaceae (FIV=24.89), Fabaceae (FIV=24.54), Rubiaceae (FIV=21.18), and Anacardiaceae (FIV= 16.03). The lowest value (FIV=1.78) was recorded for Simaroubaceae. The FIV greater than ten was recorded for eight families and greater than 30 for three families (Table 14 and figure 20).

Table 13. IVI of different tree species in the southern secondary moist deciduous forest (SSMDF)

S/No.	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	BA	RBA	IVI
1	*Terminalia paniculata*	7.68	0.10	141.45	16.13	73.68	7.07	9.44	3.47	26.67
2	*Aporosa cardiosperma*	9.85	0.14	168.42	19.20	68.42	6.57	0.84	0.31	26.08
3	*Olea dioica*	3.50	0.06	55.26	6.30	63.16	6.06	0.84	0.31	12.67
4	*Bombax ceiba*	1.22	0.05	7.24	0.83	23.68	2.27	20.70	7.60	10.70
5	*Tabernaemontana alternifolia*	4.65	0.10	51.97	5.93	44.74	4.29	0.72	0.26	10.48
6	*Bombox insigne*	1.00	0.38	0.66	0.08	2.63	0.25	25.78	9.47	9.80
7	*Careya arborea*	2.75	0.07	28.95	3.30	42.11	4.04	4.69	1.72	9.06
8	*Spondias pinnata*	1.00	0.38	0.66	0.08	2.63	0.25	22.99	8.45	8.77
9	*Schleichera oleosa*	1.94	0.04	21.71	2.48	44.74	4.29	1.98	0.73	7.50
10	*Dillenia pentagyna*	2.90	0.11	19.08	2.18	26.32	2.53	7.36	2.70	7.40
11	*Lagerstreomia microcarpa*	1.70	0.06	11.18	1.28	26.32	2.53	9.79	3.59	7.40
12	*Dalbergia sissoides.*	1.78	0.08	10.53	1.20	23.68	2.27	10.08	3.70	7.18
13	*Lagerstroemia speciosa*	1.60	0.12	5.26	0.60	13.16	1.26	13.50	4.96	6.82
14	*Terminalia elliptica*	1.80	0.14	5.92	0.68	13.16	1.26	12.81	4.70	6.64
15	*Pterocarpus marsupium*	2.43	0.13	11.18	1.28	18.42	1.77	9.73	3.57	6.62

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA- Relative basal area of the species; IVI- Importance value index of the species)

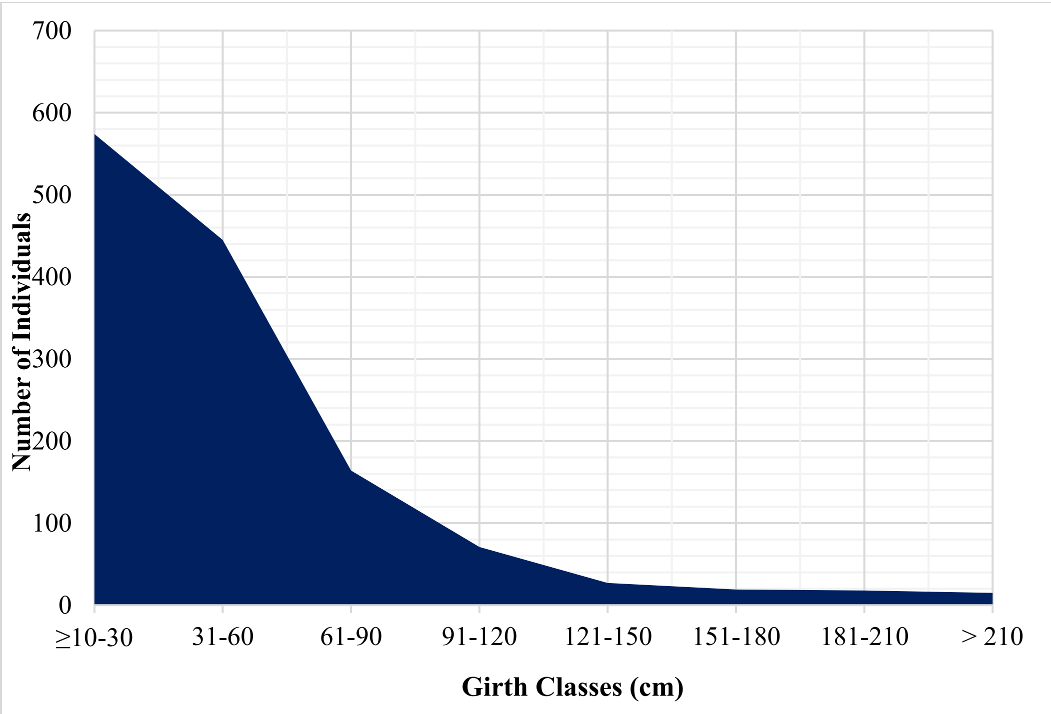


Figure 18. The girth class distribution of tree species of moist deciduous forest

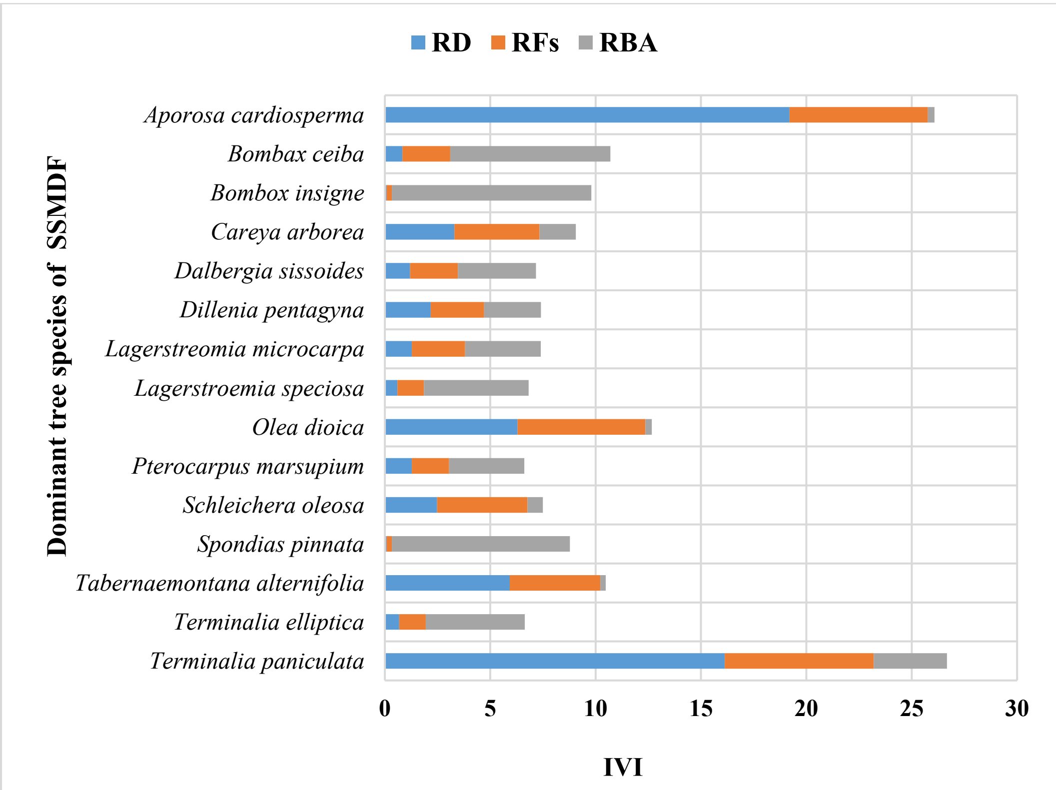


Figure 19. IVI distribution of the dominant tree species of moist deciduous forest

Table 14. IVI value of different families of southern secondary moist deciduous forest

S/No.	Family	Ds	RD	Fs	RFs	RFs	BA	RBA	IVI
1	Euphorbiaceae	266.45	30.38	178.95	17.17	2.27	14.79	5.43	52.99
2	Combretaceae	161.84	18.45	115.79	11.11	1.26	31.75	11.66	41.23
3	Malvaceae	32.24	3.68	78.95	7.58	1.52	55.73	20.47	31.73
4	Apocynaceae	96.05	10.95	100.00	9.60	1.77	11.67	4.29	24.84
5	Fabaceae	32.89	3.75	63.16	6.06	0.25	40.23	14.78	24.59
6	Rubiaceae	44.08	5.03	78.95	7.58	1.52	23.35	8.58	21.18
7	Anacardiaceae	10.53	1.20	23.68	2.27	0.25	34.17	12.55	16.03
8	Oleaceae	61.84	7.05	73.68	7.07	6.06	1.25	0.46	14.58
9	Lecythidaceae	28.95	3.30	42.11	4.04	4.04	4.69	1.72	9.06
10	Sapindaceae	21.71	2.48	44.74	4.29	4.29	1.98	0.73	7.50
11	Dilleniacaceae	19.08	2.18	26.32	2.53	2.53	7.36	2.70	7.40
12	Lythraceae	11.18	1.28	26.32	2.53	2.53	9.79	3.59	7.40
13	Xanthophyllaceae	22.37	2.55	28.95	2.78	2.78	0.61	0.22	5.55
14	Tetramelaceae	8.55	0.98	15.79	1.52	1.52	7.43	2.73	5.22
15	Lauraceae	13.16	1.50	23.68	2.27	0.51	1.64	0.60	4.37
16	Loganiaceae	10.53	1.20	21.05	2.02	2.02	2.74	1.01	4.23
17	Bignoniaceae	9.21	1.05	23.68	2.27	2.27	1.92	0.71	4.03
18	Lamiaceae	4.61	0.53	18.42	1.77	1.77	1.21	0.44	2.74

S/No.	Family	Ds	RD	Fs	RFs	RFs	BA	RBA	IVI
19	Annonaceae	3.29	0.38	10.53	1.01	1.01	3.65	1.34	2.73
20	Ebenaceae	3.95	0.45	13.16	1.26	1.26	2.04	0.75	2.46
21	Sterculiaceae	0.66	0.08	2.63	0.25	0.25	5.09	1.87	2.20
22	Flacourtiaceae	7.24	0.83	10.53	1.01	1.01	0.93	0.34	2.18
23	Rutaceae	3.95	0.45	10.53	1.01	0.76	1.86	0.68	2.14
24	Elaeocarpaceae	1.97	0.23	7.89	0.76	0.51	2.44	0.90	1.88
25	Simaroubaceae	0.66	0.08	2.63	0.25	0.25	3.90	1.43	1.76

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; IVI- Importance value index of the species)

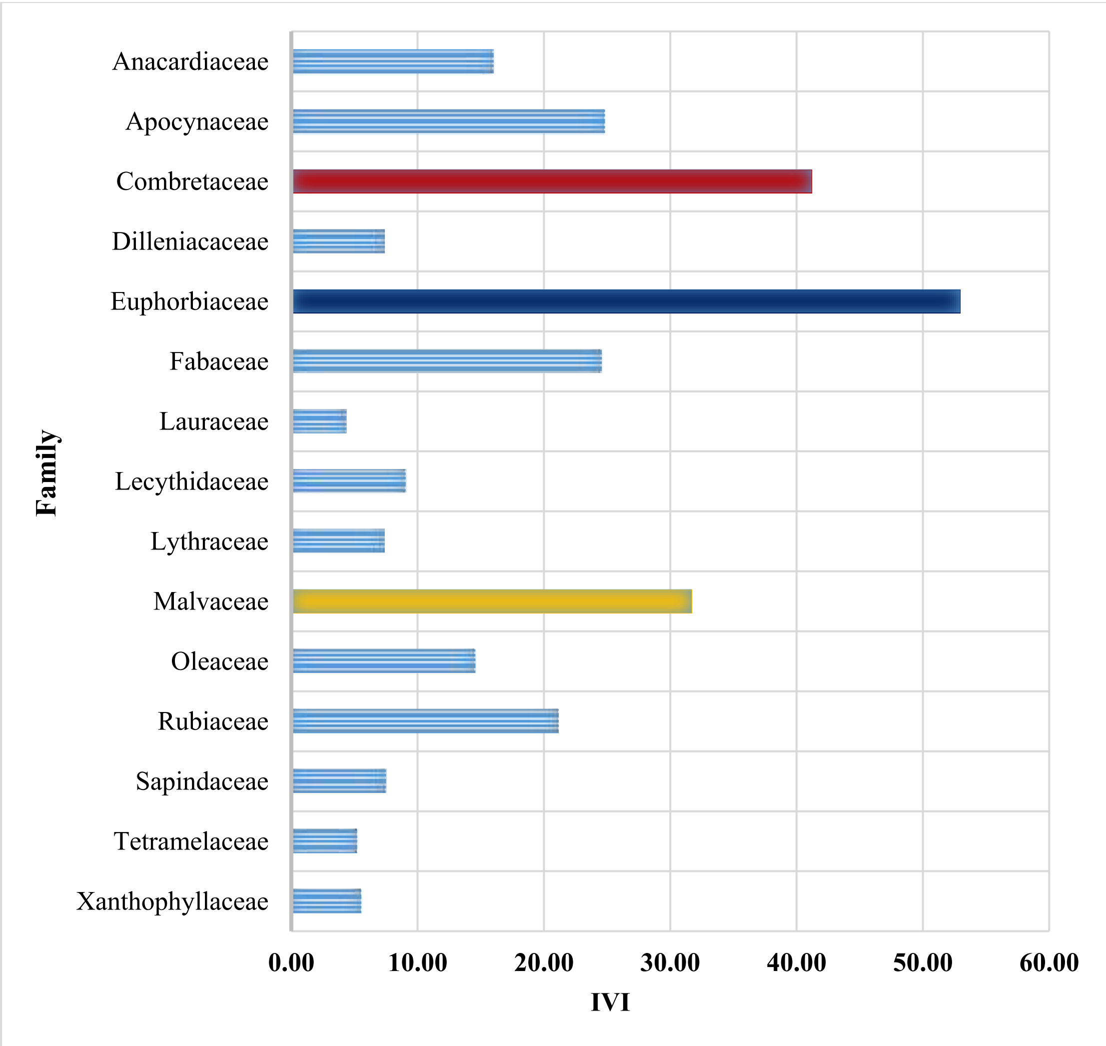


Figure 20. FIV value of dominant families of southern secondary moist deciduous forest

4.1.3.5. Floristic diversity of tree species of southern secondary moist deciduous forest

Diversity indices was calculated for the tree species of southern secondary moist deciduous forest. The dominance (D) was estimated as 0.078, Simpson index (1-D) was estimated as 0.92, for the Shannon-Weiner index (H), the value was estimated as 3.22 while for Margalef, Evenness (e^H/S), and Equitability index (J), the value was calculated as 7.92, 0.43 and 0.79 respectively (Table 15).

Table 15. Diversity indices of tree species in southern secondary moist deciduous forest

Taxa_S	58
Individuals	1333
Dominance_D	0.078
Simpson _1-D	0.92
Shannon_H	3.22
Margalef	7.92
Evenness_e^H/S	0.43
Equitability_J	0.79

4.1.3.6. Ecological distance by clustering of southern secondary moist deciduous forest

The cluster analysis grouped the whole ecosystem into five groups in the tropical moist deciduous forest based on the compositional similarities. Plots 1, 2, 3, 4,7,8,9, 11, 12, 13, 19, 24, 25, 27, 28, 29, 30, 31, and 37 were clustered as one group. Plots 5, 6, and 23 as another cluster. Plots 18, 20, 21, 22, 23, 32, 34, 35, and 36 as another cluster. Plot 10 is an independent cluster, while plots 14, 15, 16, 26, and 38 are grouped as one cluster (Figure 21).

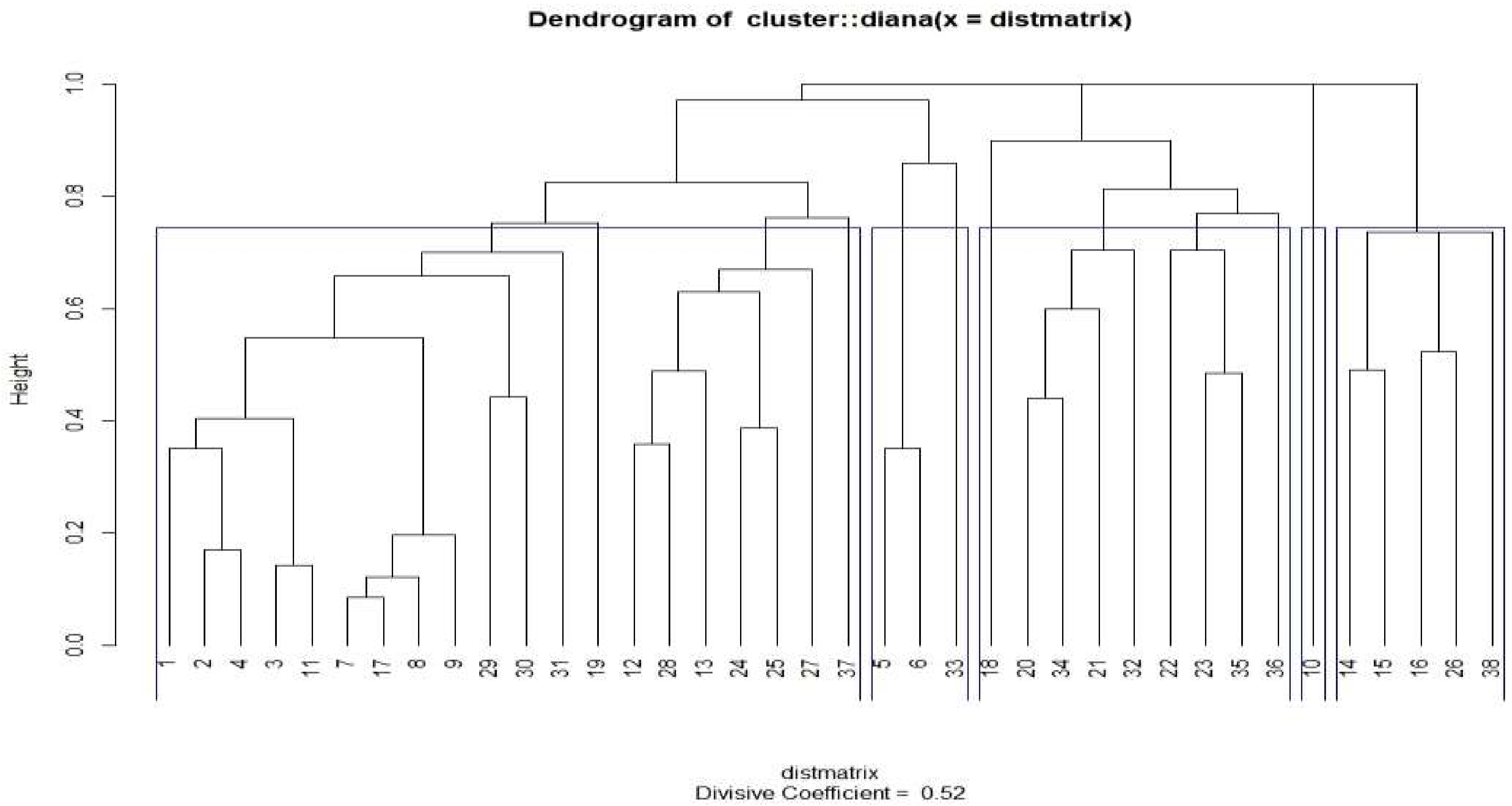


Figure 21. Cluster analysis of different plots of southern secondary moist deciduous forest

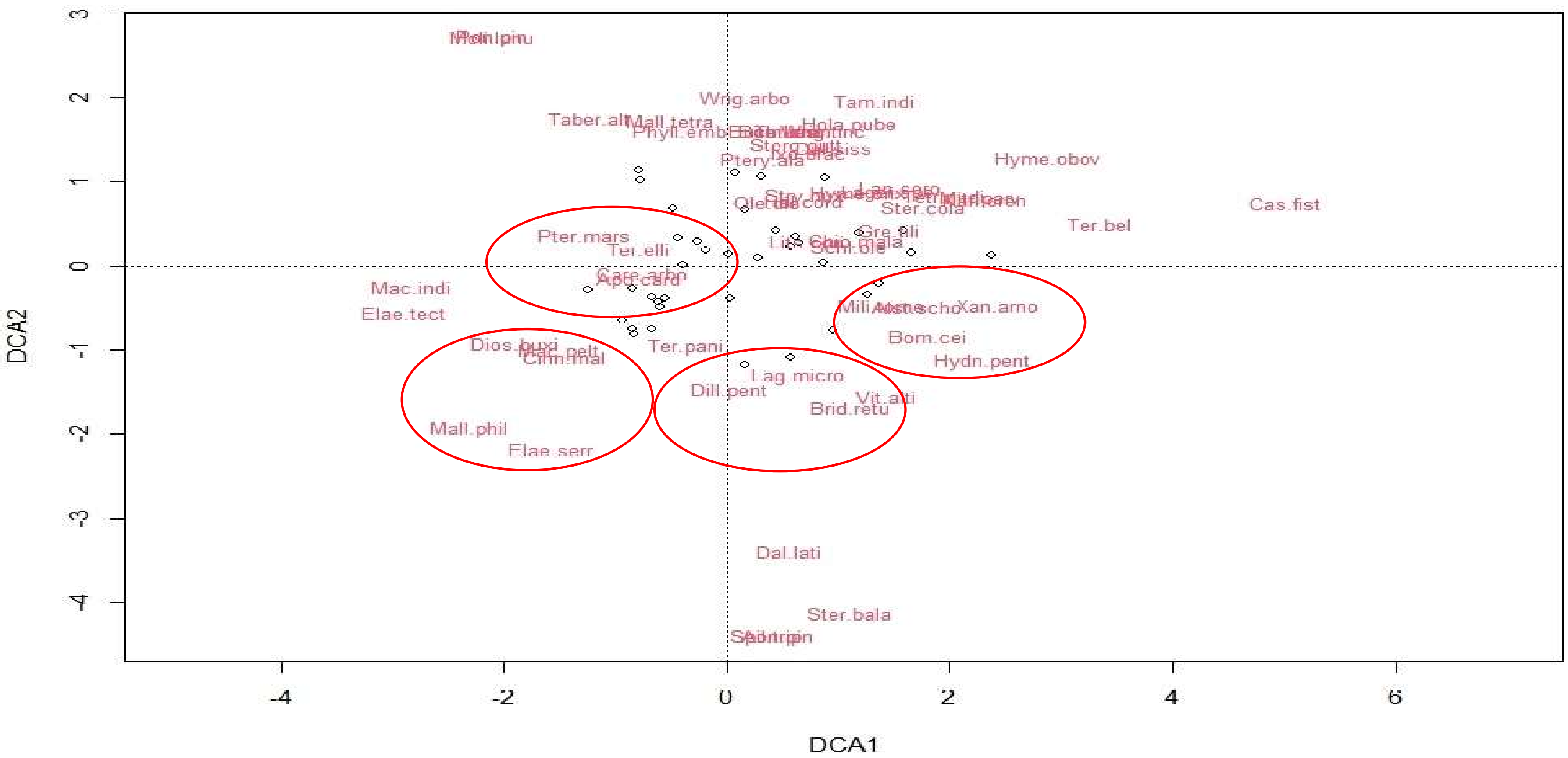


Figure 22. Detrended correspondence analysis (DCA) of different species association in moist deciduous forest

4.1.3.7. Different species assemblages in southern secondary moist deciduous forest

The detrended correspondence analysis in southern secondary moist deciduous forest identified an assemblage of species: *Pterocarpus marsupium, Terminalia elliptica, Careya arborea,* and *Aporosa cardiosperma* as one assemblage. *Terminalia paniculata*, *Lagerstroemia microcarpa, Dillenia pentagyna, Vitex altissma,* and *Bridelia retusa* as an assemblage. *Diospyros buxifolia*, *Macaranga peltata*, *Cinnamomum malabatrum* as an assemblage, and *Xanthophyllum arnottianum Hydnocarpus pentandrus*, *Bombax ceiba,* and *Alstonia scholaris* (Figure 22).

4.1.3.8. REGENERATION STATUS OF TREES SPECIES OF MOIST DECIDUOUS FOREST

4.1.3.8.1. Floristic structure of tree saplings of southern secondary moist deciduous forest

In the southern secondary moist deciduous forest, a total of 541 individual saplings belonging to 52 species with a density of 2810.39 ha^{-1} was recorded from the total sampling of 1925 m^2. The highest density (D=363.64) was recorded for *Aporosa cardiosperma* followed by (D= 244.18) *Terminalia paniculata* (D= 218.18) *Olea dioica,* (D=197.40) *Ixora brachiata* and *Tabernaemontana alternifolia* (D=176.62) and *Diospyros buxifolia* (D=155.84) respectively (Table 16).

4.1.3.8.1.1. Relative importance of tree saplings of secondary moist deciduous forest

The highest importance value index (IVI=27.50) was recorded for *Aporosa cardiosperma* followed by (IVI= 24.95) *Olea dioica,* (IVI= 18.49) *Terminalia paniculata*, (IVI=12.75) *Tabernamontana alternifolia* and *Mallotus tetracoccus* (IVI= 11.43) respectively. Three different species showed the IVI value greater than 10 (Table 16 and figure 23).

4.1.3.8.1.2. Abundance-Frequency Ratio

The ratio of abundance and frequency of saplings species of TMDF showed a range of values between 3.08-0.03. The highest abundance–frequency ratio was recorded for *Vitex altissima* followed by *Dillenia pentagyna*. Only one specie showed a value less than 0.05 (Table 16 and appendix VIII).

Table 16. The relative importance of tree saplings in the southern secondary moist deciduous forest (SSMDF)

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Aporosa cardiosperma*	1.61	0.03	316.88	13.38	49.35	14.13	27.50
2	*Olea dioica*	2.52	0.07	353.25	14.91	35.06	10.04	24.95
3	*Terminalia paniculata*	2.14	0.07	244.16	10.31	28.57	8.18	18.49
4	*Tabernaemontana alternifolia*	1.94	0.09	161.04	6.80	20.78	5.95	12.75
5	*Mallotus tetracoccus*	1.56	0.08	129.87	5.48	20.78	5.95	11.43
6	*Holarhena pubescens*	1.77	0.10	119.48	5.04	16.88	4.83	9.88
7	*Careya arborea*	1.45	0.10	83.12	3.51	14.29	4.09	7.60
8	*Mallotus philippensis*	1.30	0.10	67.53	2.85	12.99	3.72	6.57
9	*Macaranga peltata*	1.44	0.12	67.53	2.85	11.69	3.35	6.20
10	*Schleichera oleosa*	1.44	0.12	67.53	2.85	11.69	3.35	6.20
11	*Cinnamomum malabatrum*	1.38	0.13	57.14	2.41	10.39	2.97	5.39
12	*Lagerstroemia speciosa*	1.29	0.14	46.75	1.97	9.09	2.60	4.58
13	*Stereospermum colais*	2.00	0.31	51.95	2.19	6.49	1.86	4.05
14	*Diospyros buxifolia*	1.33	0.17	41.56	1.75	7.79	2.23	3.98
15	*Ixora brachiata*	1.40	0.22	36.36	1.54	6.49	1.86	3.39

(AB- Abundance; Species density; RDs –Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

4.1.3.8.2. Floristic structure of tree seedlings of SSMDF

A total of 229 individuals, consist of 35 different species with a density of 19083.33 ha^{-1} was recorded in a sampling area of 117 m^2. The highest density was recorded for *Mallotus tetracoccus* (D= 2393.16), followed by *Tabernaemontana alternifolia* (D= 1965.81) *Olea dioica* (D=1709.40), *Wrighia tinctoria* (D=1367.52), *Terminalia paniculata* (D=1282.05), *Aporosa cardiosperma* (D= 1196.58) and *Ixora brachiata* (D=940.17) respectively (Table 17).

4.1.3.8.2.1. Relative Importance of tree seedlings of SSMDF

The highest importance value index (IVI=22.92) for the tree seedlings of the tropical moist deciduous forest was recorded for *Mallotus tetracoccus* followed by *Tabernaemontana alternifolia* (IVI=19.7), *Olea dioica* (IVI=18.79) and *Aporosa cardiosperma* (IVI= 13.37) respectively. Six species showed an IVI value greater than 10, and twelve tree species showed an IVI value less than one (Table 17 and figure 24).

4.1.3.8.2.2. Abundance frequency ratio

The abundance-frequency ratio of tree seedlings species of secondary moist deciduous forest ranges between 1.7-0.07. The higher AB/F=1.17 was recorded for *Cassia fistula, Dalbergia latifolia, Dalbergia sissoides*, lowest value (AB/F =0.07) was recorded for *Olea dioica.* All the tree species showed an abundance-frequency ratio greater than 0.05 (Table 17 and appendix IX).

Table 17. IVI of the dominant tree seedlings of southern secondary moist deciduous forest

S/No.	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	IVI
1	*Mallotus tetracoccus*	1.47	0.09	2393.16	12.54	16.24	10.38	22.92
2	*Tabernaemontana alternifolia*	1.35	0.09	1965.81	10.30	14.53	9.29	19.59
3	*Olea dioica*	1.11	0.07	1709.40	8.96	15.38	9.84	18.79
4	*Aporosa cardiosperma*	1.08	0.10	1196.58	6.27	11.11	7.10	13.37
5	*Terminalia paniculata*	1.36	0.15	1282.05	6.72	9.40	6.01	12.73
6	*Wrightia tinctoria*	2.00	0.29	1367.52	7.17	6.84	4.37	11.54
7	*Ixora brachiata*	1.22	0.16	940.17	4.93	7.69	4.92	9.84
8	*Careya arborea*	1.00	0.13	769.23	4.03	7.69	4.92	8.95
9	*Diospyros buxifolia*	1.00	0.15	683.76	3.58	6.84	4.37	7.95
10	*Schleichera oleosa*	1.29	0.21	769.23	4.03	5.98	3.83	7.86
11	*Mallotus philippensis*	1.00	0.17	598.29	3.14	5.98	3.83	6.96
12	*Cinnamomum malabatrum*	1.00	0.20	512.82	2.69	5.13	3.28	5.97
13	*Macaranga peltata*	1.00	0.20	512.82	2.69	5.13	3.28	5.97
14	*Pterocarpus marsupium*	1.75	0.51	598.29	3.14	3.42	2.19	5.32
15	*Xanthophyllum arnottianum*	1.00	0.23	427.35	2.24	4.27	2.73	4.97

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

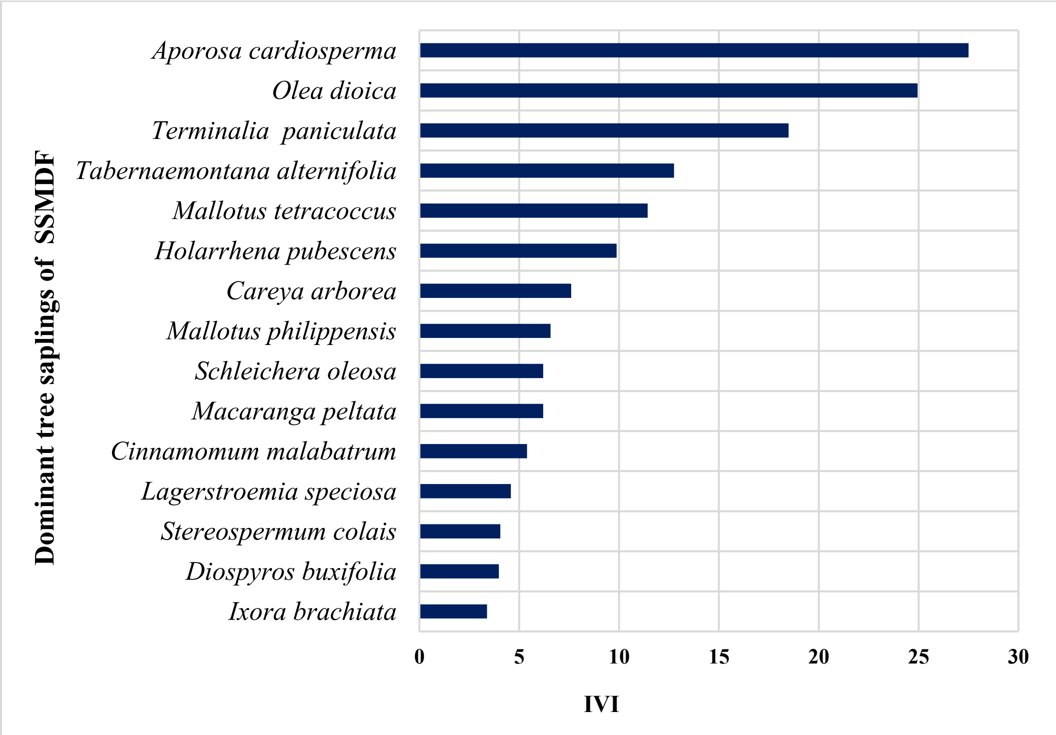


Figure 23. IVI dominant tree saplings southern secondary moist deciduous forest

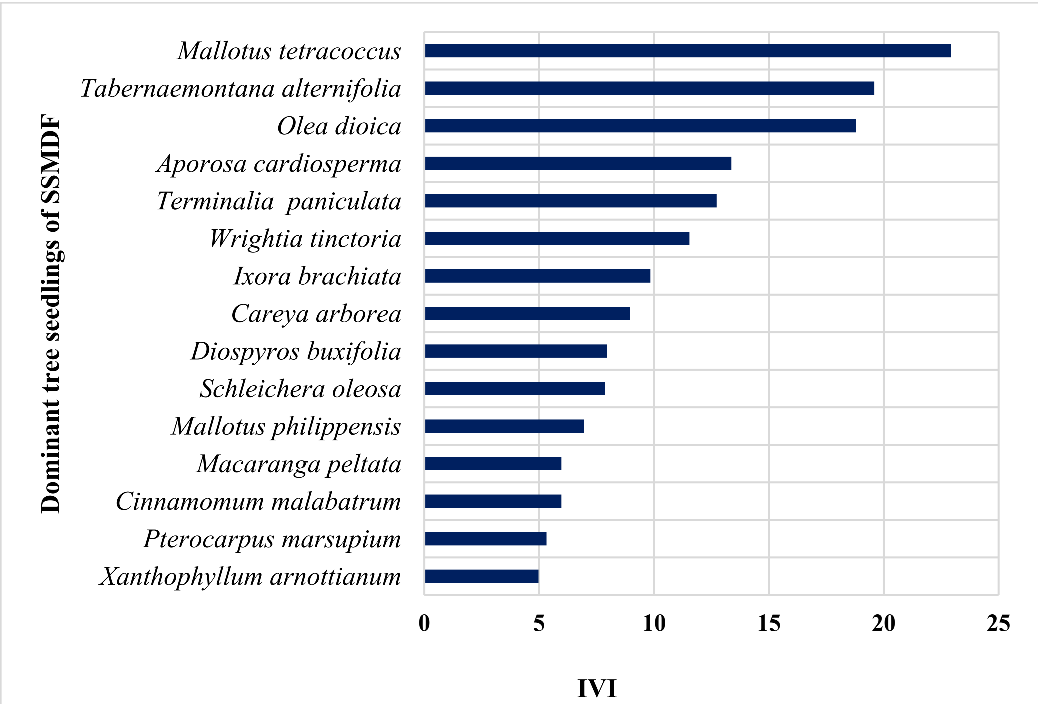


Figure 24. IVI of the dominant tree seedlings of southern secondary moist deciduous forest

4.1.3.8.3. Diversity indices of tree saplings and seedlings of southern secondary moist deciduous forest

Different diversity indices for the saplings and seedlings of SMDF were estimated and given in Table 18. The value for Shannon-Weiner's was found as 3.33 and 3.23 for seedlings, Simpson index (1-D) value was found 0.95 for saplings and 0.94 for seedlings. Margalef Index of richness was found 8.10 for saplings and 7.45 for seedlings. The evenness value was found 0.54 for saplings and 0.60 for seedlings, while the equitability index was found 0.84 for saplings and 0.86 for seedlings, respectively (Table 18 and figure 25).

Table 18 . Different diversity indices of tree saplings and seedling of SMDF

Indices	**Saplings**	**Seedlings**
Taxa	44	35
Individuals	456	229
Dominance_D	0.068	0.059
Simpson _1-D	0.93	0.94
Shannon_H	3.13	3.00
Margalef	7.023	6.27
Evenness_e^H/S	0.524	0.62
Equitability_J	0.829	0.869

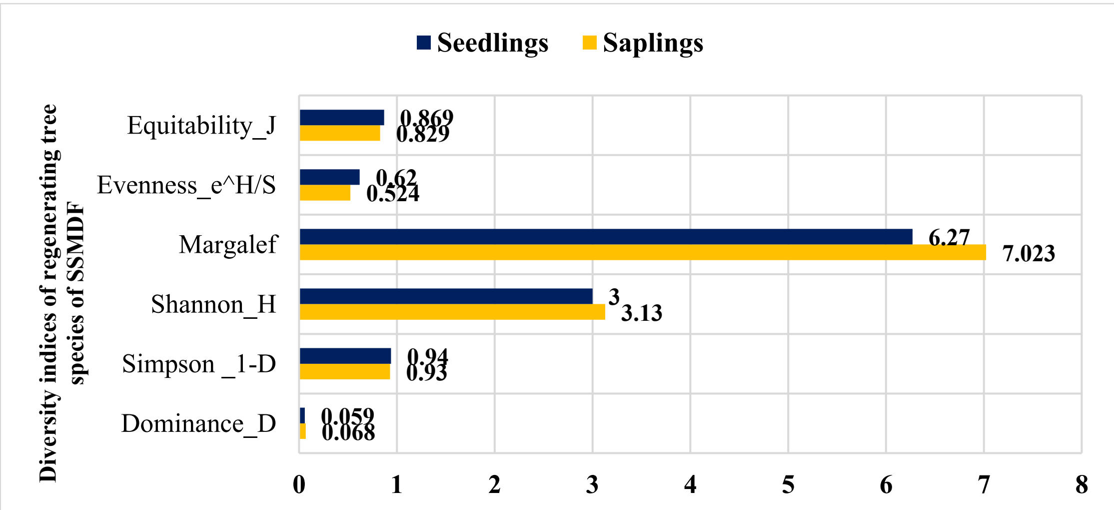


Figure 25. Diversity indices of saplings and seedlings of southern secondary moist deciduous

4.1.4. Spatial structure of tree communities of myristica swamp forest (MSF)

Myristica swamp forest is considered a unique forest ecosystem in the Shendurney wildlife sanctuary due to its constitution of the species capable of surviving in inundation throughout the year and characterized by the domination of the species belonging to the family Myristicaceae. A total of 33 species belonging to 29 genera and 19 families with a density of 1144.44 individual ha^{-1} was recorded in a total of 2700 m^2 sampling area. Out of these species, 15 species representing 45.46 % are endemic to the Western Ghats. Five species representing 15.15 % are endemic to Southern Western Ghats. For threatened categories, one species is critically endangered (CE), six species are endangered (EN), three species are in the least concern (LC) category, six species are vulnerable (VU), respectively. The detailed list of species from this ecosystem is given in Appendix X.

4.1.4.1. Girth class distribution

The girth class distribution of the myristica swamp forest was recorded for trees with a girth ≥ 10 cm (Figure 26). The girth class distribution pattern of the trees species showed the maximum number (97 species) belonging to the 10-30 cm categories. The lowest number of individuals was recorded in the >210 girth class distribution.

4.1.4.2. Relative importance of tree species of myristica swamp forest

In the myristica swamp, the dominant species are *Myristica dactyloides* (IVI=63.78), *Myristica fatua* (IVI=38.85), *Knema attenuata* (IVI=25.26), *Vateria indica* (IVI=24.69), *Holigarna arnottiana* (IVI= 17.16), *Hopea parviflora* (IVI=14.04), and *Gymnacranthera farquhariana* (IVI=12.52) whereas the lowest (IVI=1.18) was recorded for *Aporosa cardiosperma* (Table 19). The higher value of *Myristica dactyloides* is due to its density, frequency, and basal area, while for *Myristica fatua* the value is linked with specie frequency and density, respectively (figure 27).

4.1.4.3. Abundance-frequency ratio

The abundance-frequency ratio of the myristica swamp forest tree species was found within the range of 0.36-0.03. The highest value (AB/F=0.36) was recorded for *Mitragyna parviflora*, *Hopea malabarica,* and *Gomphondra coriaceae,* whereas the lowest value AB/F= 0.03 were recorded for *Hopea parviflora*, *Gymnacranthera farquhariana*, *Lopopetalum wightianum,* and *Baccaurea courtallensis*. Eight tree species showed the value of abundance-frequency ratio less than 0.05 (Table 19 and appendix X).

4.1.4.4. Relative importance of families of myristica swamp forest

In the myristica swamp forest, the dominant families are Myristicaceae (FIV=149.01), Dipterocarpaceae (FIV=41.08), Anacardiaceae (FIV=25.86), Rubiaceae (FIV=12.69), Euphorbiaceae (FIV= 11.48), and Celastraceae (FIV=10.79), whereas the lowest value (FIV= 1.44) was recorded for the family Lythraceae (Table 20). Myristicaceae is the only family having an FIV greater than 50 (figure 28).

Table 19. IVI values of tree species in Myristica Swamp Forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BAs	RBAs	IVI
1	*Myristica dactyloides*	5.00	0.05	222.22	19.42	100.00	10.26	816.04	34.11	63.78
2	*Myristica fatua*	5.42	0.05	240.74	21.04	100.00	10.26	180.71	7.55	38.85
3	*Knema attenuata*	3.50	0.04	129.63	11.33	83.33	8.55	128.95	5.39	25.26
4	*Vateria indica*	3.00	0.04	100.00	8.74	75.00	7.69	197.72	8.26	24.69
5	*Holigarna arnottiana*	2.00	0.06	29.63	2.59	33.33	3.42	266.78	11.15	17.16
6	*Hopea parviflora*	2.13	0.03	62.96	5.50	66.67	6.84	40.62	1.70	14.04
7	*Gymnacranthera farquhariana*	1.75	0.03	51.85	4.53	66.67	6.84	27.56	1.15	12.52
8	*Lophopetalum wightianum*	1.67	0.03	37.04	3.24	50.00	5.13	57.98	2.42	10.79
9	*Haldina cordifolia*	1.00	0.04	11.11	0.97	25.00	2.56	139.65	5.84	9.37
10	*Myristica malabarica*	2.50	0.08	37.04	3.24	33.33	3.42	46.49	1.94	8.60
11	*Xanthophyllum arnottianum*	1.25	0.04	18.52	1.62	33.33	3.42	75.52	3.16	8.19
12	*Baccaurea courtallensis*	1.40	0.03	25.93	2.27	41.67	4.27	1.76	0.07	6.61
13	*Lannea coromandolica*	1.00	0.12	3.70	0.32	8.33	0.85	97.53	4.08	5.25
14	*Mitraphora grandiflora*	2.50	0.15	18.52	1.62	16.67	1.71	39.07	1.63	4.96
15	*Cinnamomum malabatrum*	1.33	0.05	14.81	1.29	25.00	2.56	0.47	0.02	3.88

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; IVI- Importance value index of the species)

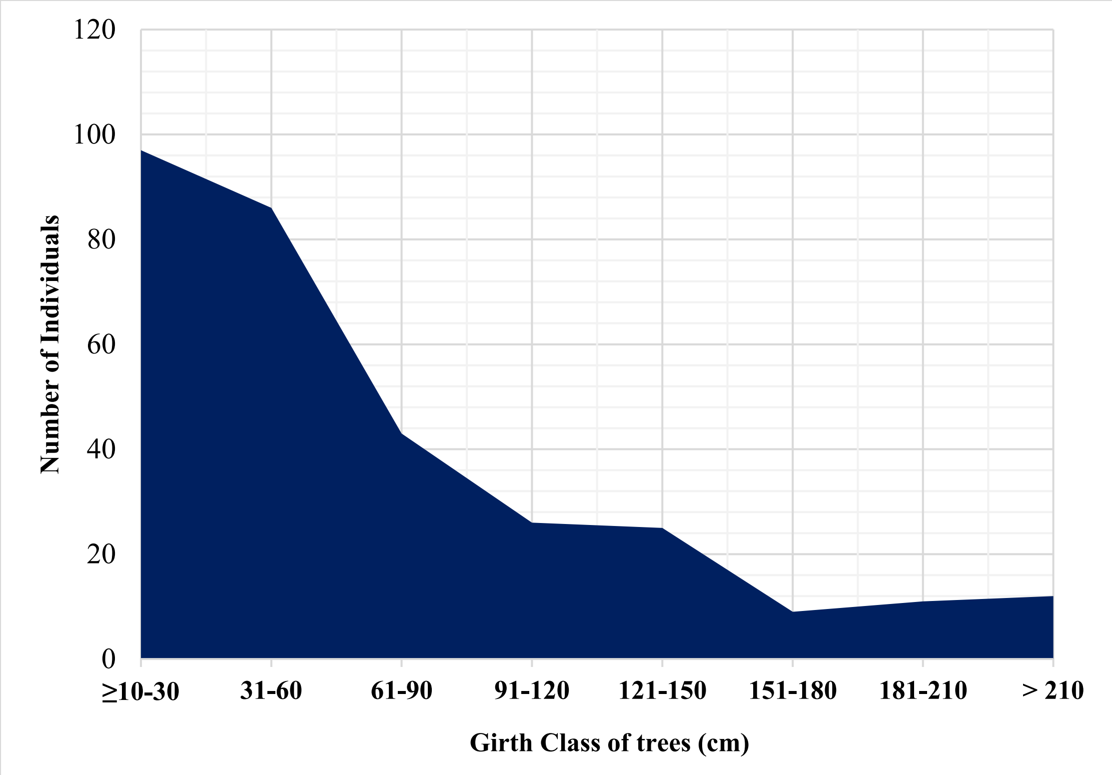


Figure 26. The girth class distribution of tree species in the myristica swamp forest

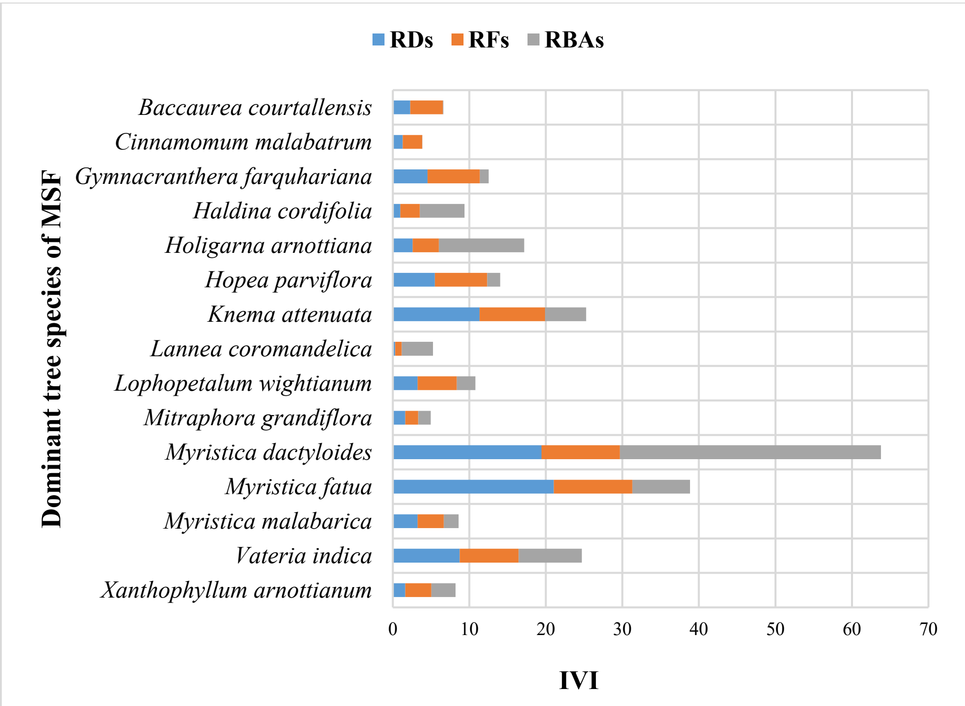


Figure 27. IVI Distribution of most dominant tree species in Myristica swamp forest

Table 20. IVI values of different families of Myristica Swamp Forest

S/No.	FAMILY	Ds	RDs	Fs	RFs	BAs	RBAs	FIV
1	Myristicaceae	681.48	59.55	383.33	39.32	1199.75	50.14	149.01
2	Dipterocarpaceae	174.07	15.21	150.00	15.38	250.90	10.49	41.08
3	Anacardiaceae	40.74	3.56	50.00	5.13	410.97	17.18	25.86
4	Rubiaceae	22.22	1.94	33.33	3.42	175.31	7.33	12.69
5	Euphrbiaceae	37.04	3.24	58.33	5.98	54.15	2.26	11.48
6	Celastraceae	37.04	3.24	50.00	5.13	57.98	2.42	10.79
7	Polygalaceae	18.52	1.62	33.33	3.42	75.52	3.16	8.19
8	Fabaceae	14.81	1.29	33.33	3.42	11.43	0.48	5.19
9	Annonaceae	18.52	1.62	16.67	1.71	39.07	1.63	4.96
10	Ebenaceae	18.52	1.62	25.00	2.56	11.33	0.47	4.66
11	Lauraceae	14.81	1.29	25.00	2.56	0.47	0.02	3.88
12	Flacourtiaceae	7.41	0.65	16.67	1.71	31.93	1.33	3.69
13	Meliaceae	7.41	0.65	16.67	1.71	25.13	1.05	3.41
14	Calophyllaceae	7.41	0.65	16.67	1.71	22.21	0.93	3.29
15	Clusiaceae	11.11	0.97	16.67	1.71	7.76	0.32	3.00
16	Rutaceae	11.11	0.97	16.67	1.71	2.97	0.12	2.80
17	Cornaceae	7.41	0.65	16.67	1.71	7.70	0.32	2.68
18	Asteraceae	11.11	0.97	8.33	0.85	1.86	0.08	1.90
19	Lythraceae	3.70	0.32	8.33	0.85	6.17	0.26	1.44

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; IVI- Importance value index of the species)

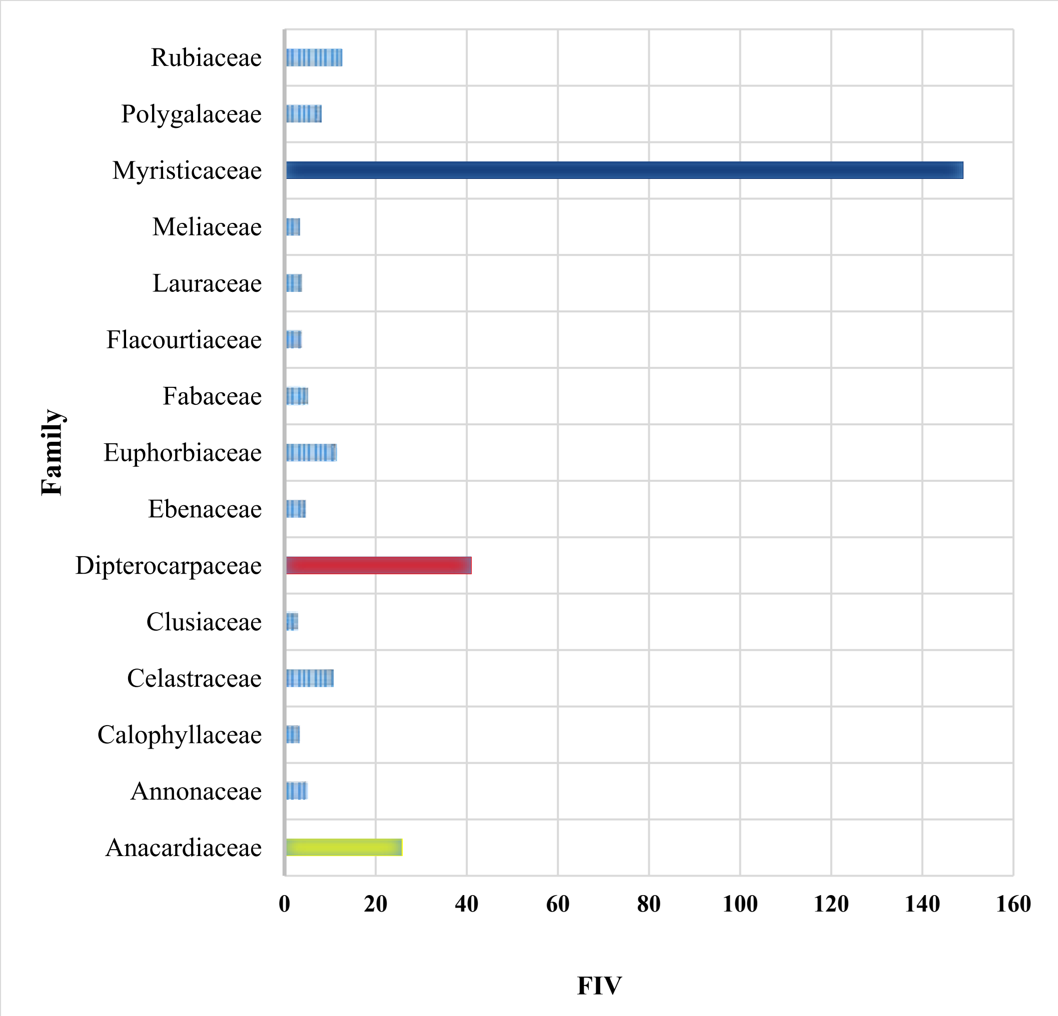


Figure 28. FIV values of dominant families of myristica swamp forest

4.1.4.5. Diversity indices of tree species of myristica swamp forest

Different diversity indices of the myristica swamp forest were estimated. The value of dominance (D) was recorded as 0.11, Simpson index (1-D) was estimated as 0.88, Shannon and Weiner index (H) as 2.70, whereas Margalef, evenness (e^H/S), and equitability (J) indices were recorded as 5.58, 0.44 and 0.76 respectively (Table 21).

Table 21. Diversity indices of tree species in Myristica swamp Forest

Taxa_S	33
Individuals	309
Dominance_D	0.11
Simpson _1-D	0.88
Shannon_H	2.70
Margalef	5.58
Evenness_e^H/S	0.44
Equitability_J	0.76

4.1.4.6. Ecological distance by clustering in myristica swamp forest

For myristica swamp forest (MSF), the cluster analysis divided the ecosystem into five clusters. The first cluster constituted the plots 1, 2, 3, 7, and 10. The second cluster constituted the plots 4, 5, and 9. The third cluster constituted plots 6 and 8, while plots 11 and 12 were individual clusters (figure 29).

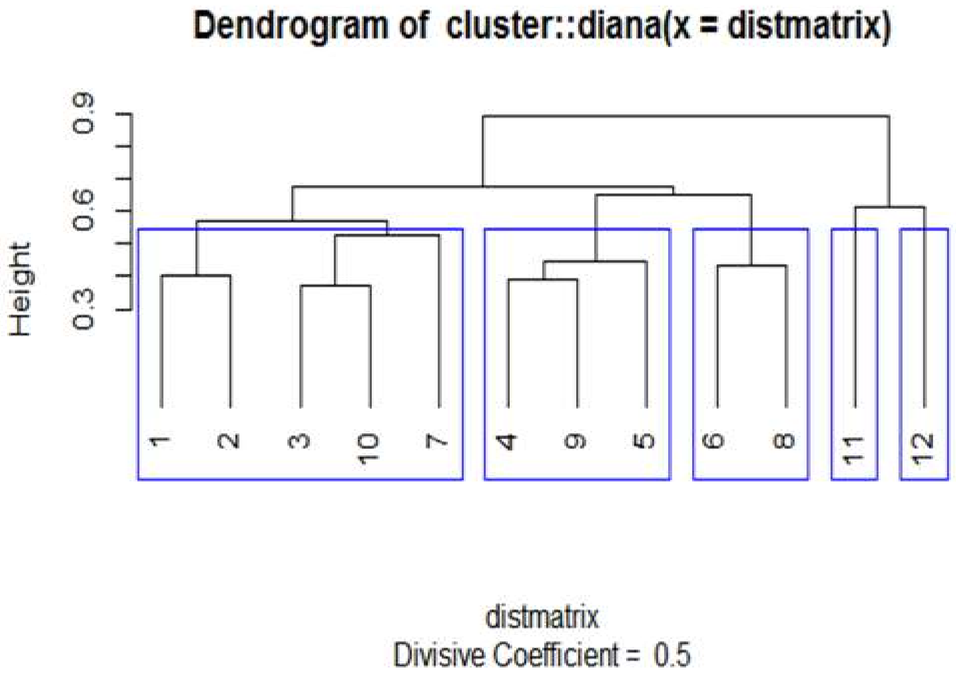


Figure 29. Cluster analysis of different plots in myristica swamp forest

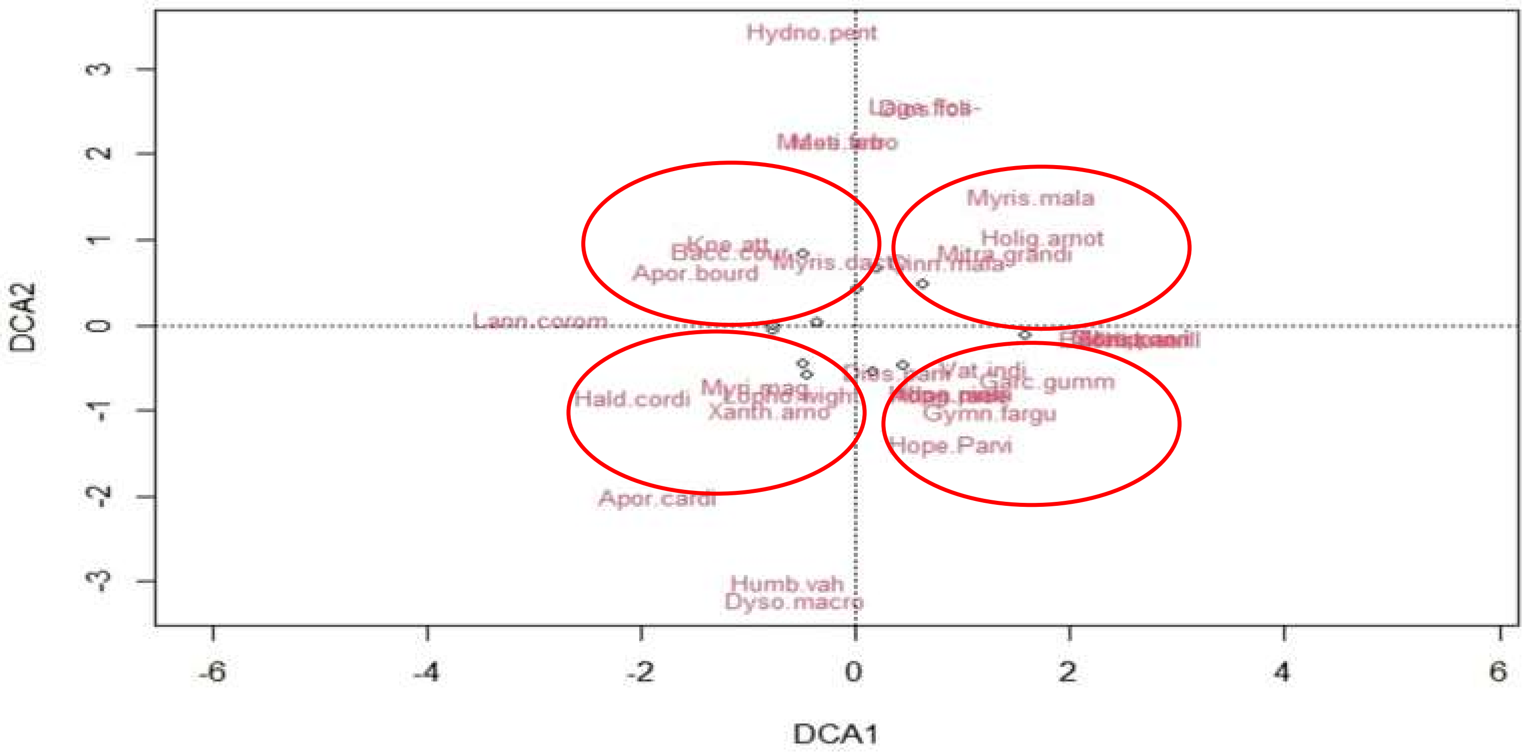


Figure 30. Detrended correspondence analysis (DCA) of different species association in Myristica Swamp forest

4.1.4.7. Different tree species assemblages in Myristica swamp forest

The detrended correspondence analysis identified different species assemblages of the myristica swamp forest, such as *Knema attenuata*, *Aporosa bourdillonii*, *Myristica dactyloides*, and *Baccaurea courtallensis*. Another assemblage *of Myristica malabarica, Holigarna arnottiana*, *Mitragyna parviflora,* and *Cinnamomum malabatrum* was also identified. *Vateria indica*, *Hopea parviflora*, *Garcinia gummi-gutta,* and *Gymnacranthera farquhariana* as another assemblage. *Myristica fatua*, *Haldina cordifolia, Xanthaphyllum arnottianum,* and *Lophatopelum wightianum* constituted another assemblage (Figure 30).

4.1.4.8. REGENERATION STATUS OF TREE SPECIES OF MYRISTICA SWAMP FOREST

4.1.4.8.1. Floristic structure of tree saplings of myristica swamp forest

In the myristica swamp forest, a total of 153 tree saplings belonging to 29 species with a density of 2448 ha^{-1} was recorded from the sampling area of 625 m^2. The highest density (D= 336.00) was recorded for *Knema attenuata*, followed by *Gymnacranthera farquhariana* (D= 208.00), (D= 176.00) was recorded for *Myristica dactyloides, Hopea parviflora,* and *Myristica fatua,* respectively (Table 22).

4.1.4.8.1.1. Relative importance of tree saplings of myristica swamp forest

The most dominant tree saplings of myristica swamp forest are *Knema attenuata* (IVI=21.23), (IVI= 13.01) for *Gymnacranthera farquhariana* and *Myristica dactyloides*, and (IVI=10.96) for *Hopea parviflora,* respectively. Six species showed the lowest importance value of (IVI= 137) (Table 22 and appendix XI).

4.1.4.8.1.2. Abundance-frequency ratio

The abundance frequency ratio of tree saplings in myristica swamp forest ranged between 0.50-0.04. The lower value (AB/F=0.04) was recorded for *Myristica dactyloides* and *Cinnamomum malabatrum* (Table 22 and appendix XI).

Table 22. IVI of the dominant tree saplings of Myristica Swamp Forest (MSF)

S/No.	Name of Specie	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Knema attenuata*	2.10	0.05	336.00	14.38	40.00	6.85	21.23
2	*Gymnacranthera farquhariana*	2.17	0.09	208.00	8.90	24.00	4.11	13.01
3	*Myristica dactyloides*	1.38	0.04	176.00	7.53	32.00	5.48	13.01
4	*Hopea parviflora*	2.20	0.11	176.00	7.53	20.00	3.42	10.96
5	*Myristica fatua*	2.20	0.11	176.00	7.53	20.00	3.42	10.96
6	*Myristica malabarica*	2.00	0.10	160.00	6.85	20.00	3.42	10.27
7	*Cinnamomum malabatrum*	1.00	0.04	112.00	4.79	28.00	4.79	9.59
8	*Hydnocarpus pentandra*	1.33	0.06	128.00	5.48	24.00	4.11	9.59
9	*Viteria indica*	1.40	0.07	112.00	4.79	20.00	3.42	8.22
10	*Diospyros buxifolia*	1.20	0.06	96.00	4.11	20.00	3.42	7.53
11	*Holigarna arnottiana*	1.75	0.11	112.00	4.79	16.00	2.74	7.53
12	*Baccaurea courtallensis*	1.50	0.09	96.00	4.11	16.00	2.74	6.85
13	*Syzygium travancoricum*	1.50	0.19	48.00	2.05	8.00	1.37	3.42
14	*Aporosa cardiosperma*	1.00	0.13	32.00	1.37	8.00	1.37	2.74
15	*Grewia serrulata*	1.00	0.13	32.00	1.37	8.00	1.37	2.74

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

4.1.4.8.2. Floristic structure of tree seedlings in myristica swamp forest

A total of 101 individual seedlings belonging to 26 species with a density of 25250 ha^1 was recorded from the sampling area of 40 m^2. The highest density (D= 4000.00) was recorded for *Myristica dactyloides* followed by *Cinnmomum malabatrum* (D= 2750.00) and *Knema attenuata* (D=192.00) (Table 23).

4.1.4.8.2.1. Relative Importance of tree seedlings in myristica swamp forest

The highest importance value (IVI= 26.54) of tree seedlings of myristica swamp forest was recorded for *Myristica dactyloides* followed by *Cinnomomum malabatrum* (IVI= 20.48), *Knema attenuata* (IVI= 19.49), while (IVI=11.42) was recorded for *Holigarna arnottiana*, *Vateria indica*, and *Myristica fatua* respectively (Table 23).

4.1.4.8.2.1. Abundace-frequency ratio

The abundance and frequency ratio of tree seedlings of the myristica swamp was estimated. The value ranged between 0.80-0.06. The highest value (AB/F= 0.80) was recorded for *Murraya paniculata.* All the species showed an AB/F value greater than 0.05 (Table 23 and appendix XII).

Table 23. Relative importance of the tree seedlings of Myristica Swamp forest (MSF)

S/No	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	IVI
1	*Myristica dactyloides*	1.60	0.06	4000.00	15.84	25.00	13.70	29.54
2	*Cinnamomum malabatrum*	1.57	0.09	2750.00	10.89	17.50	9.59	20.48
3	*Knema attenuata*	1.43	0.08	2500.00	9.90	17.50	9.59	19.49
4	*Holigarna arnottiana*	1.50	0.15	1500.00	5.94	10.00	5.48	11.42
5	*Myristica fatua*	1.50	0.15	1500.00	5.94	10.00	5.48	11.42
6	*Vateria indica*	1.50	0.15	1500.00	5.94	10.00	5.48	11.42
7	*Diospyros buxifolia*	1.00	0.10	1000.00	3.96	10.00	5.48	9.44
8	*Hopea parviflora*	1.67	0.22	1250.00	4.95	7.50	4.11	9.06
9	*Baccaurea courtallensis*	1.33	0.18	1000.00	3.96	7.50	4.11	8.07
10	*Hydnocarpus pentandra*	1.33	0.18	1000.00	3.96	7.50	4.11	8.07
11	*Leea indica*	1.33	0.18	1000.00	3.96	7.50	4.11	8.07
12	*Gymnacranthera farquhariana*	1.50	0.30	750.00	2.97	5.00	2.74	5.71
13	*Myristica malabarica*	1.50	0.30	750.00	2.97	5.00	2.74	5.71
14	*Olea dioica*	1.50	0.30	750.00	2.97	5.00	2.74	5.71
15	*Grewia serrulata*	1.00	0.20	500.00	1.98	5.00	2.74	4.72

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

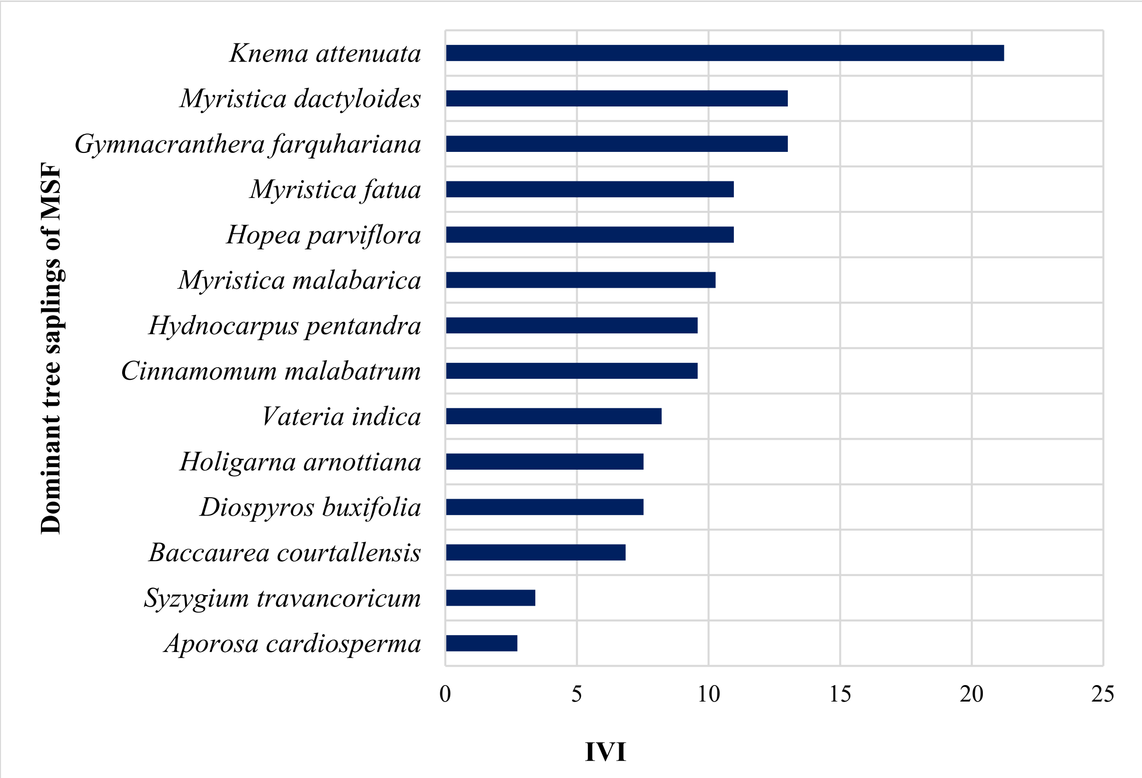


Figure 31. IVI of most dominant tree saplings of myristica swamp

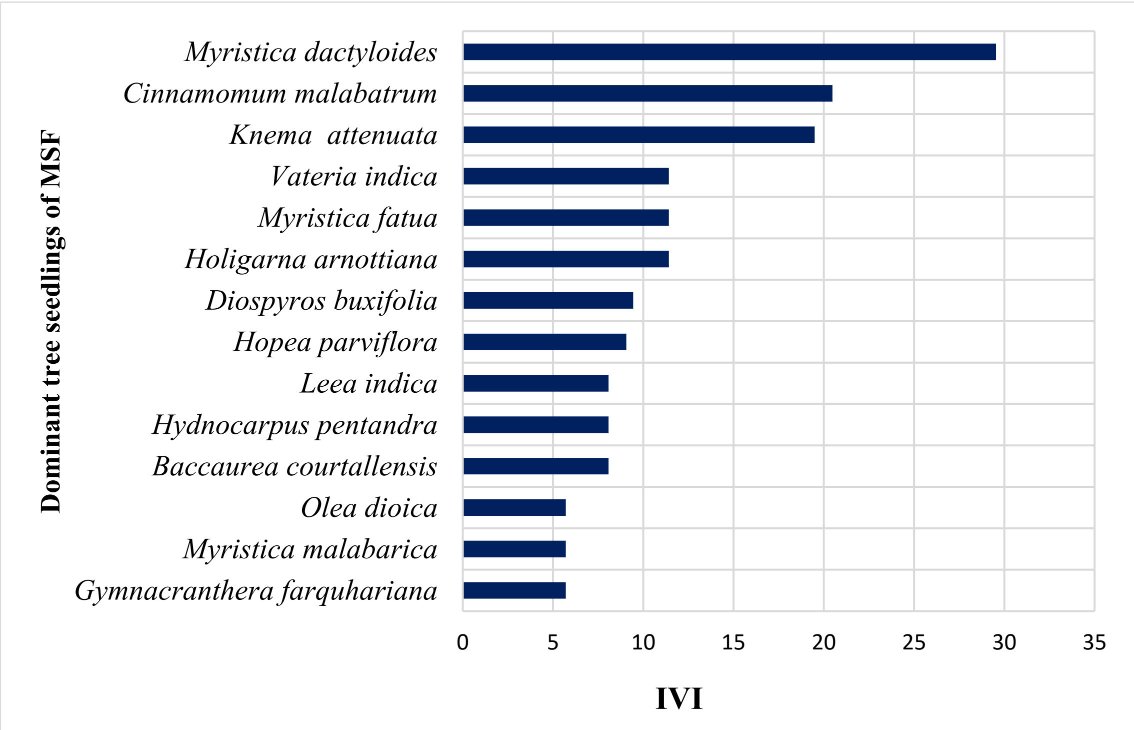


Figure 32. IVI of the dominant tree saplings of myristica swamp forest

4.1.4.8.3. Diversity indices of tree saplings and seedlings of myristica swamp forest

Diversity indices of regenerating species of both saplings and seedlings of Myristica swamp forest were estimated. The value of dominance (D) was found 0.066 for saplings and 0.071 for seedlings. The Simpson index (1-D) was found 0.93 for saplings and 0.91 for tree seedlings. The Shannon-weiners index (H), value was found 2.97 for saplings and 2.91 for seedlings. Margalef value was found 5.62 for saplings and 5.42 for tree seedlings. The evenness (e^H/S) and equitability (J) values were found 0.67 and 0.88 for tree saplings and 0.70 and 0.89 for tree seedlings, respectively (Table 24 and figure 33).

Table 24. Diversity indices of regenerating tree saplings and seedlings of myristica swamp forest.

Diversity Indices	Saplings	Seedlings
Taxa_S	29	26
Individuals	146	101
Dominance_D	0.066	0.071
Simpson _1-D	0.93	0.91
Shannon_H	2.97	2.91
Margalef	5.62	5.42
Evenness_e^H/S	0.67	0.70
Equitability_J	0.88	0.89

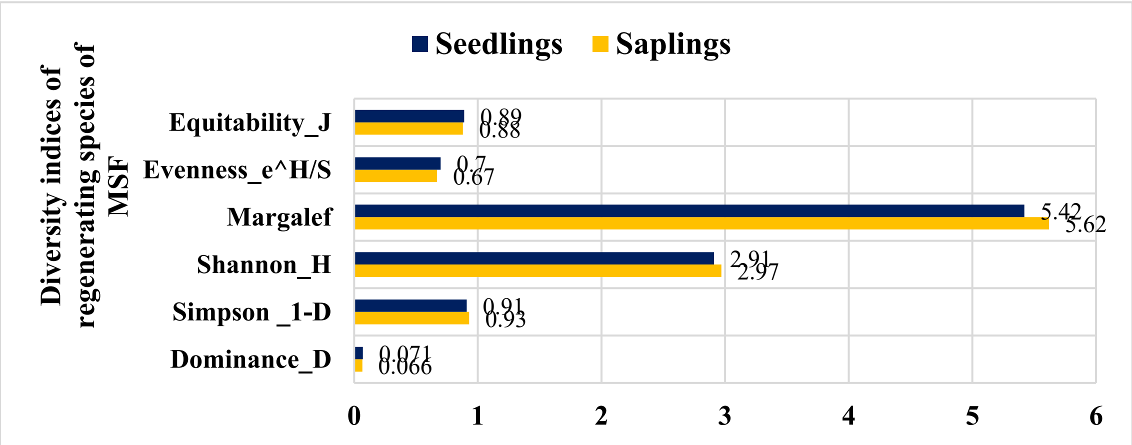


Figure 33. Diversity indices of tree saplings and seedlings of myristica swamp forest

4.1.5. Spatial structure of tree communities in the tropical hilltop forest

In the tropical hilltop forest, 44 tree species belonging to 24 families and 33 genera with a density of 619.00 ha^{-1} were recorded. Twelve species representing 27.27 % are endemic to the Western Ghats, and 16 species representing 36.36 % are endemic to Southern Western Ghats. For threatened categories, seven species are endangered (EN), ten species are vulnerable to extinction in the near future. The detailed list of enumerated species from this ecosystem is given in the appendix XIII.

4.1.5.1 Girth class distribution

The girth class distribution of the hilltop forest was recorded for trees with a girth ≥ 10 cm (Figure 34). The distribution of the trees showed the i J-shaped distribution with decreasing density with increasing girth size (Figure 34). The lower girth class (10-30 cm) occupied the higher number of individuals trees, while the lowest number of species was recorded in the >210 girth class category.

4.1.5.2. Relative importance of tree species of tropical hilltop forest

The most dominant species in this forest are *Vernonia travancorica* (IVI=18.95) followed by *Symplocos cochinchinensis* (IVI=15.05), *Elaeocarpus munronii* (IVI=13.36) *Gluta travancorica* (IVI=11.75). The higher IVI for *Vernonia travancorica*, *Symplocos cochinchinensis. Elaeocarpus munronii* is attributed to the species with higher relative density and frequency. In contrast, for *Gluta travancorica,* the higher importance value is associated with the species's relative basal area (Table 25 and figure 35).

4.1.5.3. Abundance-frequency ratio

The abundance frequency ratio of tree species of hilltop tropical forest ranges between 0.36-0.05. The highest value (AB/F= 0.36) was recorded for *Gluta travancorica*, followed by *Litsea Keralana* (AB/F=0.28) whereas the lowest value (AB/F=0.05) was recorded for *Goniothalamus rhynchantherus.* All tree species showed an AB/F greater than 0.05 (Table 25 and appendix XIII).

4.1.5.4. Relative importance of families of tropical hilltop forest

The dominant families of the tropical hilltop forest are Lauraceae (FIV= 69.92), followed by Clusiaceae (FIV= 35.71), Myrtaceae (FIV= 24.00), Asteraceae (FIV= 18.95), Myrsinaceae (FIV= 18.63). Symplocaceae (FIV=15.05) and Elaocapaceae (FIV= 13.36) respectively. The lowest familial importance value index (FIV=2.67) was recorded for the family Oleaceae. Nine families showed an FIV value greater than 10 (Table 26 and figure 36).

Table 25. IVI values of different tree species in the tropical hilltop forest

S/No.	Name of Specie	AB	AB/F	Ds	RD	Fs	RF	BA	RBA	IVI
1	*Vernonia travancorica*	5.50	0.10	76.39	12.33	55.56	5.68	1.35	0.93	18.95
2	*Symplocos cochinchinensis*	4.22	0.08	52.78	8.52	50.00	5.11	2.06	1.42	15.05
3	*Elaeocarpus munronii*	3.22	0.06	40.28	6.50	50.00	5.11	2.53	1.74	13.36
4	*Gluta travancorica*	2.00	0.36	2.78	0.45	5.56	0.57	15.59	10.74	11.75
5	*Neolitsea scrobiculata*	3.17	0.10	26.39	4.26	33.33	3.41	3.58	2.46	10.13
6	*Ficus tsjahela*	1.00	0.18	1.39	0.22	5.56	0.57	12.04	8.29	9.08
7	*Bhesa indica*	1.80	0.06	12.50	2.02	27.78	2.84	6.05	4.17	9.02
8	*Garcinia travancorica*	1.83	0.06	15.28	2.47	33.33	3.41	4.34	2.99	8.87
9	*Litsea oleoides*	3.25	0.15	18.06	2.91	22.22	2.27	5.21	3.59	8.78
10	*Litsea floribunda*	3.00	0.09	25.00	4.04	33.33	3.41	1.38	0.95	8.39
11	*Calophyllum polyanthum*	2.50	0.23	6.94	1.12	11.11	1.14	8.80	6.06	8.32
12	*Poecilonueron indicus*	2.00	0.09	11.11	1.79	22.22	2.27	6.02	4.15	8.21
13	*Cinnamomum sulpharatum*	2.17	0.07	18.06	2.91	33.33	3.41	2.22	1.53	7.85
14	*Actinodaphne malabarica*	2.60	0.09	18.06	2.91	27.78	2.84	2.96	2.04	7.79
15	*Agrostistachys borneensis*	2.00	0.18	5.56	0.90	11.11	1.14	8.16	5.62	7.65

(AB- Abundance ; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA– Relative basal area of the species; IVI- Importance value index of the species)

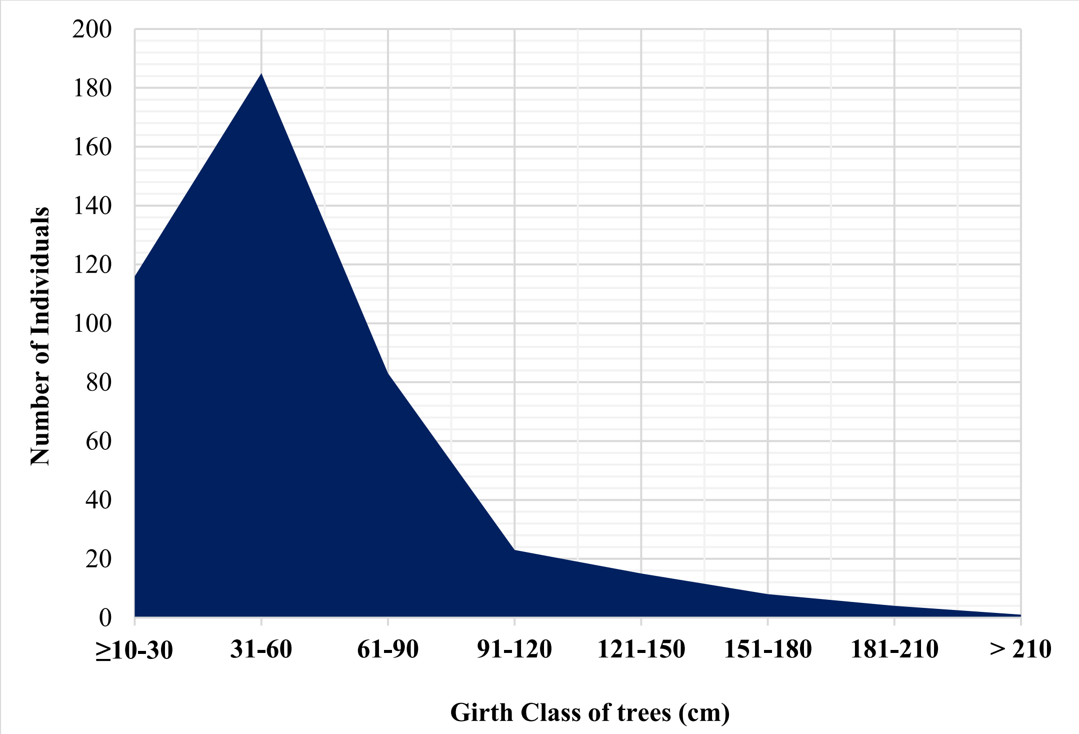


Figure 34. The girth class distribution of tree species of hilltop tropical forest

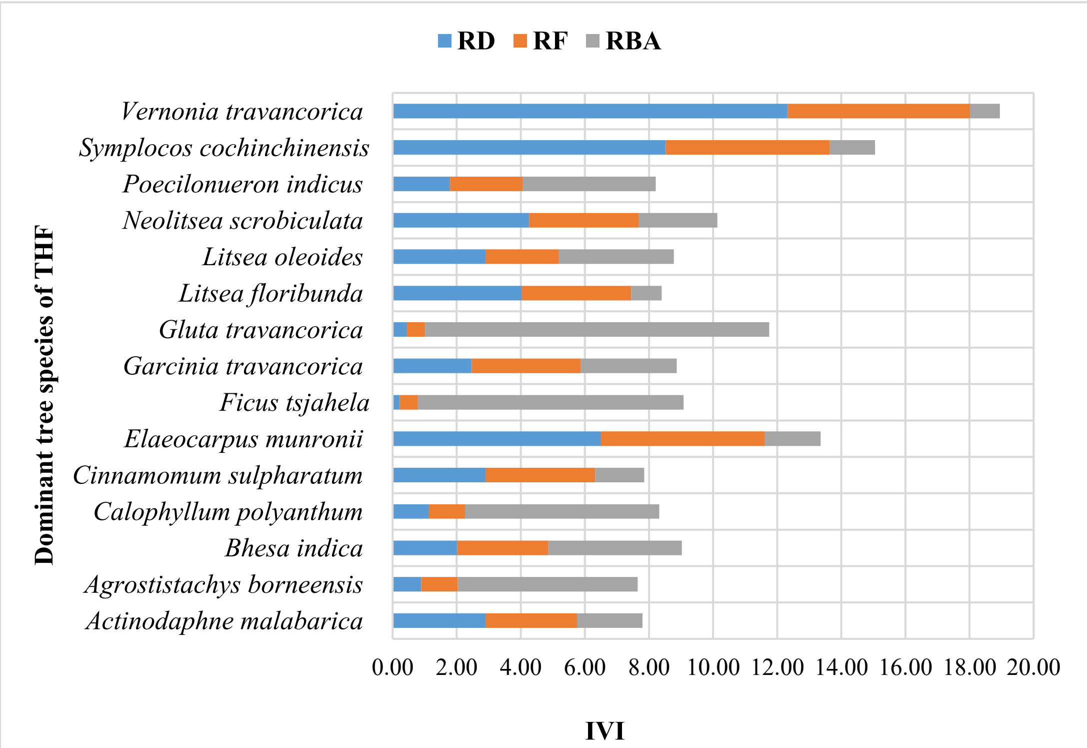


Figure 35. IVI distribution of most dominant tree species of tropical hilltop forest

Table 26. IVI value of different families of tropical hilltop forest

S/No.	FAMILY	D	RD	F	RF	BA	RBA	FIV
1	Lauraceae	165.28	26.68	250.00	25.57	25.66	17.67	69.92
2	Clusiaceae	51.39	8.30	100.00	10.23	24.96	17.18	35.71
3	Myrtaceae	56.94	9.19	100.00	10.23	6.65	4.58	24.00
4	Asteraceae	76.39	12.33	55.56	5.68	5.68	0.93	18.95
5	Myrsinaceae	50.00	8.07	88.89	9.09	2.12	1.46	18.63
6	Symplocaceae	52.78	8.52	50.00	5.11	2.06	1.42	15.05
7	Elaeocarpaceae	40.28	6.50	50.00	5.11	2.53	1.74	13.36
8	Anacardiaceae	2.78	0.45	5.56	0.57	15.59	10.74	11.75
9	Annonaceae	15.28	2.47	50.00	5.11	4.81	3.31	10.89
10	Moraceae	1.39	0.22	5.56	0.57	12.04	8.29	9.08
11	Calestraceae	12.50	2.02	27.78	2.84	2.84	4.17	9.02
12	Euphorbiaceae	5.56	0.90	11.11	1.14	8.16	5.62	7.65
13	Staphyleaceae	12.50	2.02	22.22	2.27	3.28	2.26	6.55
14	Meliaceae	16.67	2.69	16.67	1.70	2.70	1.86	6.26
15	Achariaceae	11.11	1.79	22.22	2.27	2.73	1.88	5.95
16	Theaceae	6.94	1.12	22.22	2.27	3.54	2.43	5.83

S/No.	FAMILY	D	RD	F	RF	BA	RBA	FIV
17	Cornaceae	9.72	1.57	16.67	1.70	2.96	2.04	5.31
18	Sapindaceae	1.39	0.22	5.56	0.57	6.44	4.44	5.23
19	Sabiaceae	9.72	1.57	16.67	1.70	2.76	1.90	5.17
20	Rutaceae	8.33	1.35	22.22	2.27	0.57	0.39	4.01
21	Ulmaceae	1.39	0.22	5.56	0.57	3.57	2.46	3.25
22	Stemonuraceae	4.17	0.67	11.11	1.14	1.81	1.24	3.05
23	Rubiaceae	4.17	0.67	11.11	1.14	1.32	0.91	2.71
24	Oleaceae	2.78	0.45	11.11	1.14	1.58	1.08	2.67

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; IVI- Importance value index of the species)

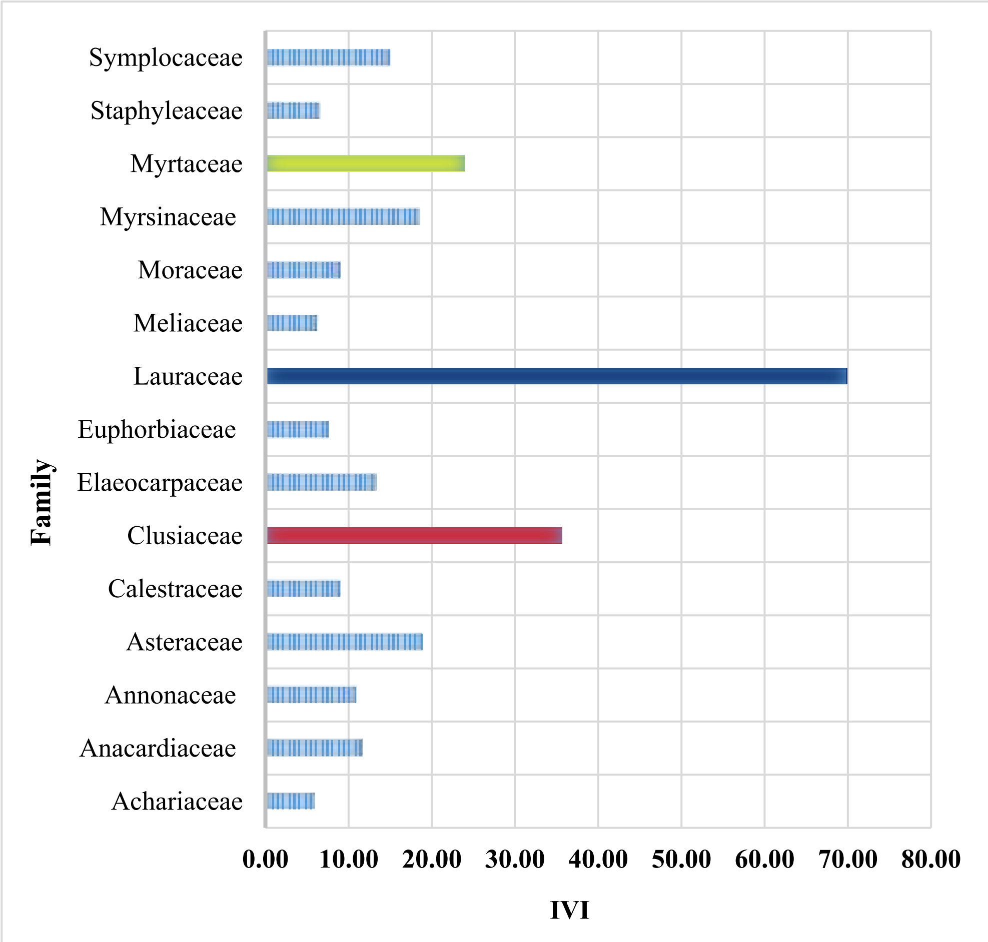


Figure 36. IVI values of the dominant families of tropical hilltop forest

4.1.5.5. Different diversity indices of tropical hilltop forest

Diversity indices were estimated for the tropical hilltop forest. The dominance (D) was estimated as 0.044, Simpson (1-D) was estimated as 0.95, Shannon (H) as 3.44, Margalef as 7.05, Evenness (e^H/S) as 0.70, while 0.90 was estimated for equitability (J) index (Table 27).

Table 27. Diversity indices for the tree species of tropical hilltop forest

Taxa_S	44
Individuals	446
Dominance_D	0.044
Simpson _1-D	0.95
Shannon_H	3.44
Margalef	7.05
Evenness_e^H/S	0.70
Equitability_J	0.90

4.1.5.6. Ecological distance by clustering of tropical hilltop forest

The cluster analysis grouped the whole 18 plots into 5 clusters in the tropical hilltop forest based on the compositional similarities. Plot 2, 3, 4, 5, and 6 as one cluster Plot 7 and 8 as one cluster. Plot 9, 10, and 11 as one cluster, plot 12, 13, 14, 15, 16, 17, and 18 as another cluster while plot one is an independent cluster (figure 37).

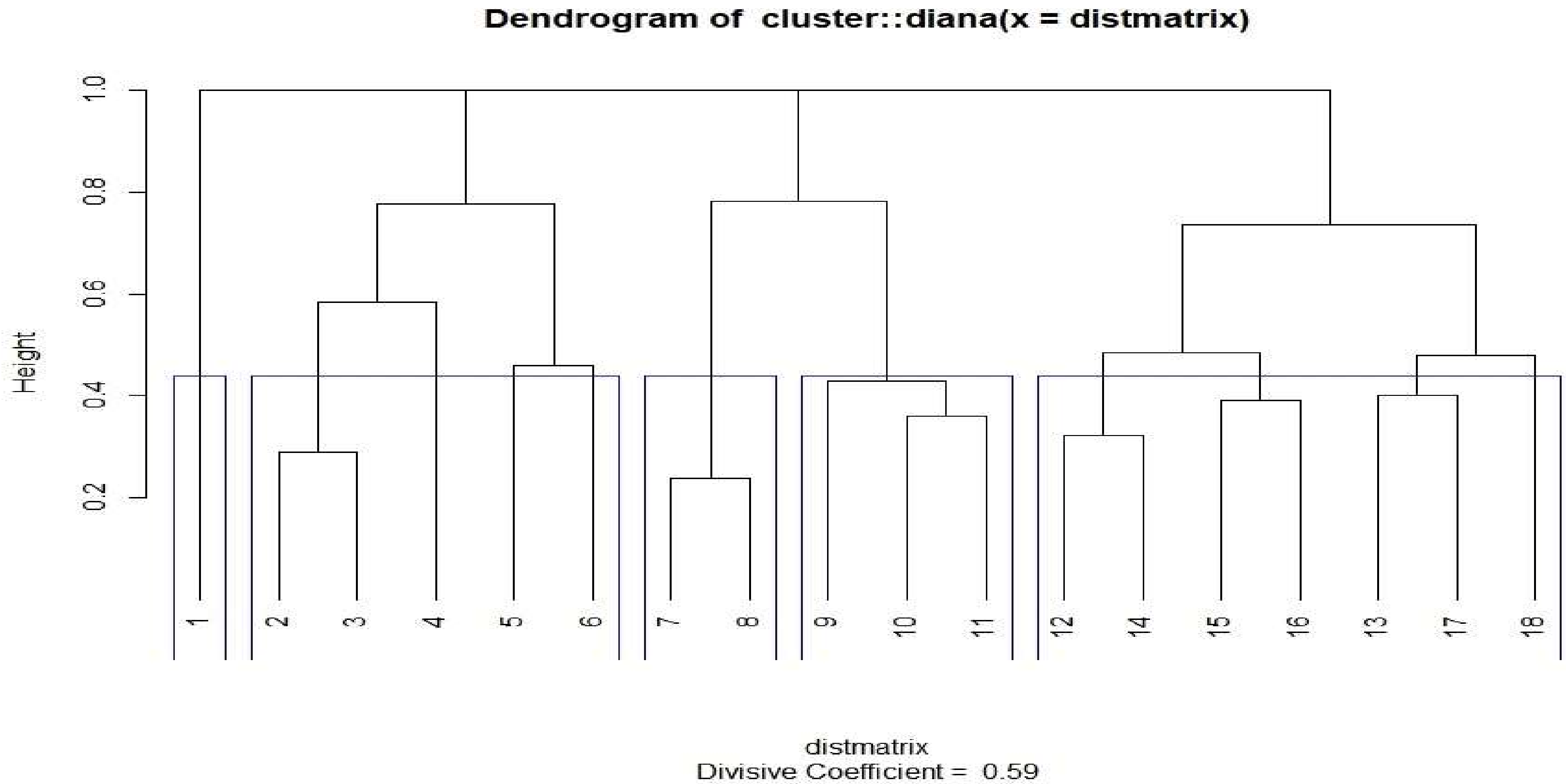


Figure 37. Cluster analysis of different plots of tropical hilltop forest

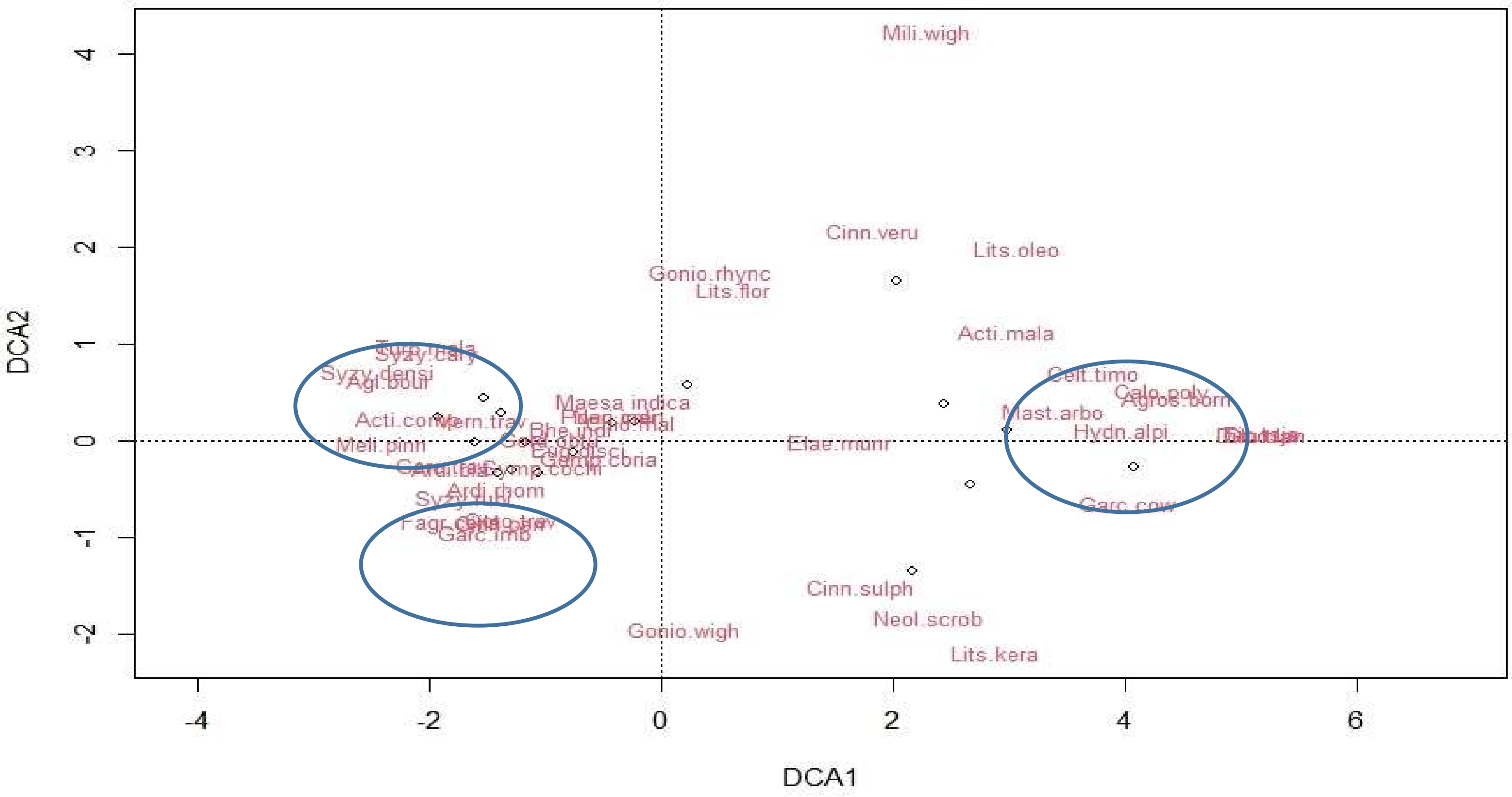


Figure 38. Detrended correspondence analysis (DCA) of different tree species association in in tropical hilltop forest

4.1.5.7. Different tree species assemblages in a tropical hilltop forest

The detrended correspondence analysis identified three different species assemblages of tropical hilltop forest: *Turpania malabarica*, *Aglaia bourdillonii, Syzygium densiflorum,* and *Syzgium caryophyllatum.* Another assemblage of *Ardisia rhomboifolia*, *Syzygium rubicundum, Garcinia tavancorica*, *Fagraea ceilanica,* and *Garcinia imbertii*. Species assemblage like *Calophyllum polyanthum, Mastixia arborea, Agrostistachys borneensis,* and *Hydnocarpus alpine* was also recognised (figure 38).

4.1.5.8. REGENERATION STATUS OF TREE SPECIES OF TROPICAL HILLTOP FOREST

4.1.5.8.1. Floristic structure of tree saplings of THF

A total of 231 individuals saplings belonging to 37 species with a density of 2800 ha^{-1} was recorded from the sampling area of 825 m^2. The highest density (D= 339.39) was recorded for *Cinnomomum sulpharatum* followed by *Litsea floribunda* (D= 254.55) and *Ardisia rhomboidea* (D= 157.58) (Table 28).

4.1.5.8.1.1. Relative importance of saplings species of THF

The highest importance value index (IVI =20.02) was recorded for *Cinnamomum sulpharatum* followed by (IVI= 16.99) for *Litsea floribunda*, *Ardisia rhomboidea* (IVI= 10.89), and *Actinodaphne malabarica* (IVI= 10.03) (Table 28).

4.1.5.8.1.2. Abundance –frequency ratio

The Abundance-frequency ratio of the tree saplings of tropical hilltop forests ranges between 0.66-0.09. The highest value was recorded for *Calophyllum polyanthum* and the lowest for *Litsea floribunda.* All the species showed an AB/F value greater than 0.05 (Table 28 and appendix XIV).

Table 28. IVI of the tree saplings of tropical hilltop forest

S/No.	Name of Species	AB	AB/F	D	RDs	Fs	RFs	IVI
1	*Cinnamomum sulpharatum*	3.11	0.11	339.39	12.12	27.27	7.89	20.02
2	*Litsea floribonda*	2.33	0.09	254.55	9.09	27.27	7.89	16.99
3	*Ardisia rhomboidea*	2.17	0.12	157.58	5.63	18.18	5.26	10.89
4	*Actinodaphne malabarica*	1.83	0.10	133.33	4.76	18.18	5.26	10.03
5	*Elaeocarpus munronii*	1.67	0.09	121.21	4.33	18.18	5.26	9.59
6	*Caseara macrocarpa*	3.00	0.25	145.45	5.19	12.12	3.51	8.70
7	*Symplocos cochinchinensis*	1.80	0.12	109.09	3.90	15.15	4.39	8.28
8	*Litsea keralana*	2.75	0.23	133.33	4.76	12.12	3.51	8.27
9	*Vernonia travancorica*	1.40	0.09	84.85	3.03	15.15	4.39	7.42
10	*Litsea oleoides*	2.25	0.19	109.09	3.90	12.12	3.51	7.40
11	*Eugenia discifera*	2.00	0.17	96.97	3.46	12.12	3.51	6.97
12	*Syzygium densiflorum*	2.67	0.29	96.97	3.46	9.09	2.63	6.09
13	*Neolitsea scrobiculata*	1.25	0.10	60.61	2.16	12.12	3.51	5.67
14	*Actinodaphne campunulata*	2.33	0.26	84.85	3.03	9.09	2.63	5.66
15	*Fagraea ceilanica*	2.00	0.22	72.73	2.60	9.09	2.63	5.23

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

4.1.5.8.2. Floristic structure of tree seedlings of tropical hilltop forest

In a 42 m^2 sampling area, 89 individual seedlings belonging to 27 species with a density of 21190 ha^{-1} were recorded. The highest importance value index (D= 2142.86) was recorded for *Ardisia rhomboidea* followed by *Litsea floribunda* (D=1904.76) and *Cinnamomum sulpharatum* and *Actinodaphne malabarica* and *Syzygium densiflorum,* respectively (D= 1428.57) (Table 29).

4.1.5.8.2.1. Relative importance of seedlings species of THF

The highest importance value index (IVI = 17.44) was recorded for *Litsea floribunda* followed by *Ardisia rhomboidea* (IVI= 17.16), *Cinnamomum sulpharatum* (IVI=16.03), (IVI= 12.38) for *Actinodaphne malabarica* and *Syzygium densiflorum*. The lowest importance value (IVI=2.53) was recorded for *Aglaia bourdillonii*, *Cinnamomum verum*, *Eugenia discifera*, *Garcinia travancorica*, *Mastixia arborea,* and *Neolitsea scrobiculata,* respectively (Table 29).

4.1.5.8.2.2. Abundance- frequency ratio

The abundance-frequency ratio ranged between 0.42-0.09. The highest value AB/F= 0.42 were recorded for *Cinnamomum perrottetti*, *Aglaia bourdillonii*, *Cinnamomum verum*, *Eugenia discifera,* whereas the lowest AB/F= 0.09 was recorded for *Litsea floribunda.* All the tree species showed an abundance-frequency ratio greater than 0.05 (Table 29 and appendix XV).

Table 29. IVI of tree seedlings of tropical hilltop forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Litsea floribunda*	1.33	0.09	1904.76	8.99	14.29	8.45	17.44
2	*Ardisia rhomboidea*	1.80	0.15	2142.86	10.11	11.90	7.04	17.16
3	*Cinnamomum sulpharatum*	1.60	0.13	1904.76	8.99	11.90	7.04	16.03
4	*Actinodaphne malabarica*	1.50	0.16	1428.57	6.74	9.52	5.63	12.38
5	*Syzygium densiflorum*	1.50	0.16	1428.57	6.74	9.52	5.63	12.38
6	*Elaeocarpus munronii*	1.25	0.13	1190.48	5.62	9.52	5.63	11.25
7	*Litsea oleoides*	1.00	0.11	952.38	4.49	9.52	5.63	10.13
8	*Symplocos cochinchinensis*	1.00	0.11	952.38	4.49	9.52	5.63	10.13
9	*Vernonia travancorica*	1.00	0.11	952.38	4.49	9.52	5.63	10.13
10	*Actinodaphne campunulata*	1.00	0.14	714.29	3.37	7.14	4.23	7.60
11	*Cinnomumum perrottetti*	2.00	0.42	952.38	4.49	4.76	2.82	7.31
12	*Hydnocarpus alpina*	1.50	0.32	714.29	3.37	4.76	2.82	6.19
13	*Maesa indica*	1.50	0.32	714.29	3.37	4.76	2.82	6.19
14	*Bhesa indica*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
15	*Calophyllum polyanthum*	1.00	0.21	476.19	2.25	4.76	2.82	5.06

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

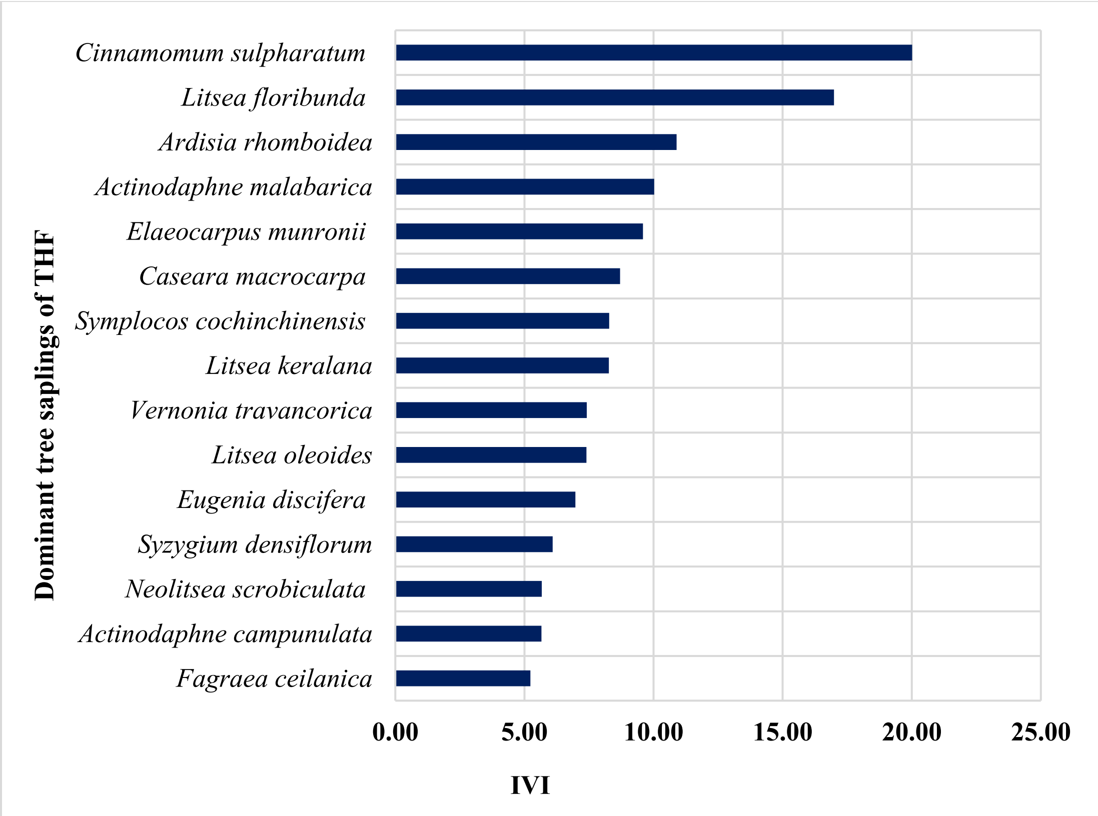


Figure 39. IVI of the tree saplings of tropical hilltop forest

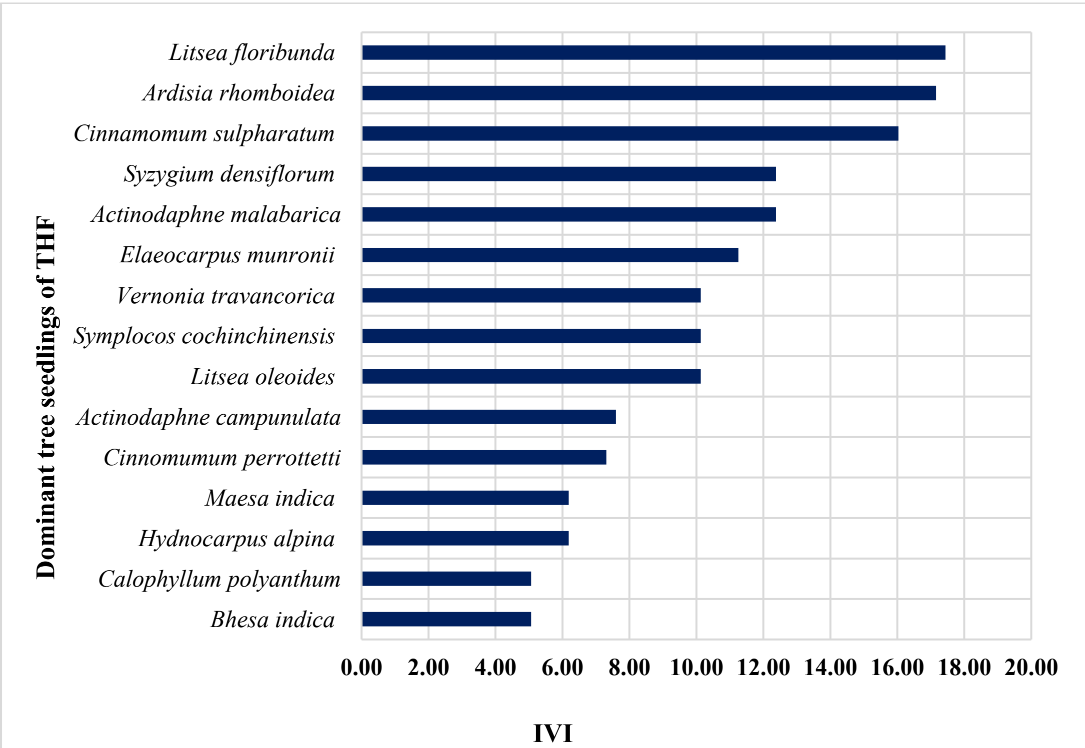


Figure 40. IVI of the tree seedlings in tropical hilltop forest

4.1.5.8.3. Diversity indices of tree saplings and seedlings of tropical hilltop forest

The diversity indices of tree regeneration of tropical hilltop forest was estimated. The dominance (D) was found at 0.048 for saplings and 0.053 for seedlings. The Simpson index (1-D) was found 0.95 for saplings and 0.94 for tree seedlings. The Shannon-weiners index (H), the value was found to be 3.27 for saplings and 3.07 for seedlings. Margalef value was found 6.43 for saplings and 5.79 for tree seedlings. The evenness (e^H/S) and equitability (J) values were found to be and 073 and 0.80 and 0.91 and 0.93 for saplings and seedlings, respectively (Table 30 and Figure 41).

Table 30. Diversity indices of the tree regeneration of tropical hilltop forest

Diversity Indices	Saplings	Seedlings
Taxa_S	36	27
Individuals	231	89
Dominance_D	0.048	0.054
Simpson _1-D	0.95	0.94
Shannon_H	3.27	3.07
Margalef	6.43	5.79
Evenness_e^H/S	0.73	0.80
Equitability_J	0.91	0.93

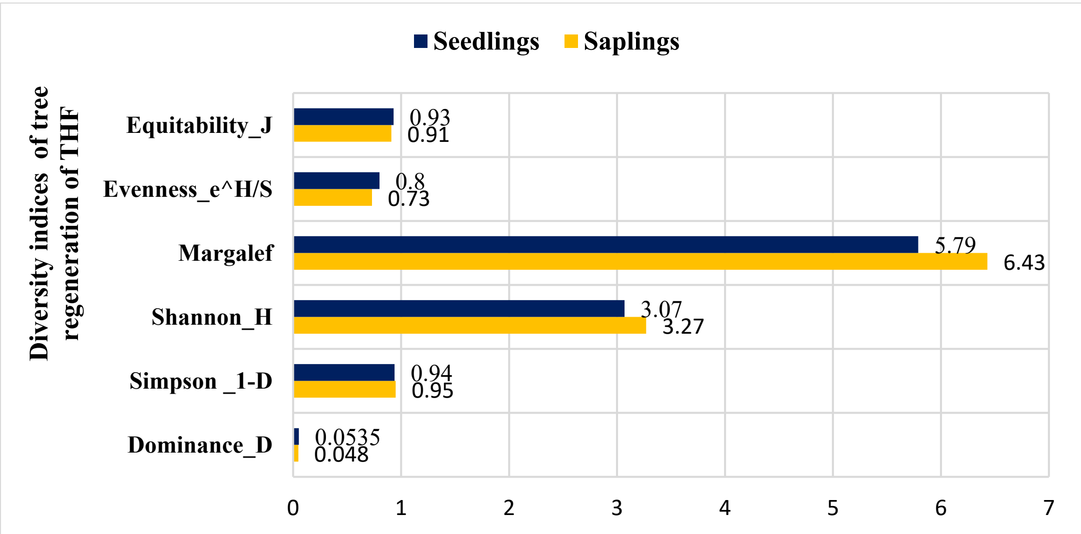


Figure 41. Diversity indices of tree regeneration of tropical hilltop forest

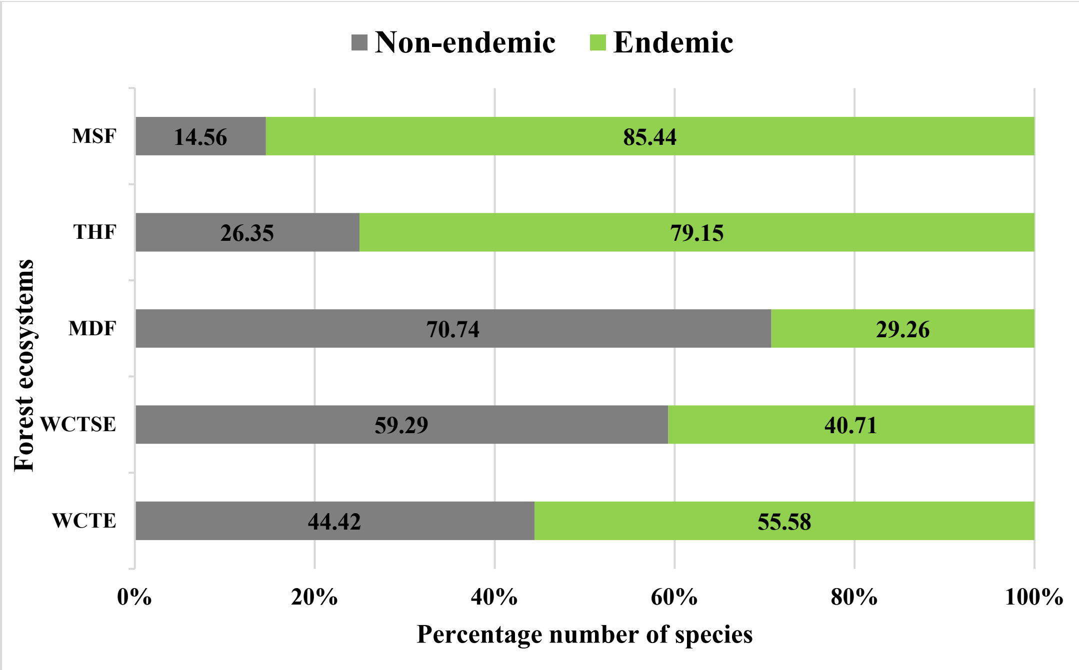


Figure 42. Percentage endemic composition of tree species in all the forest ecosystems

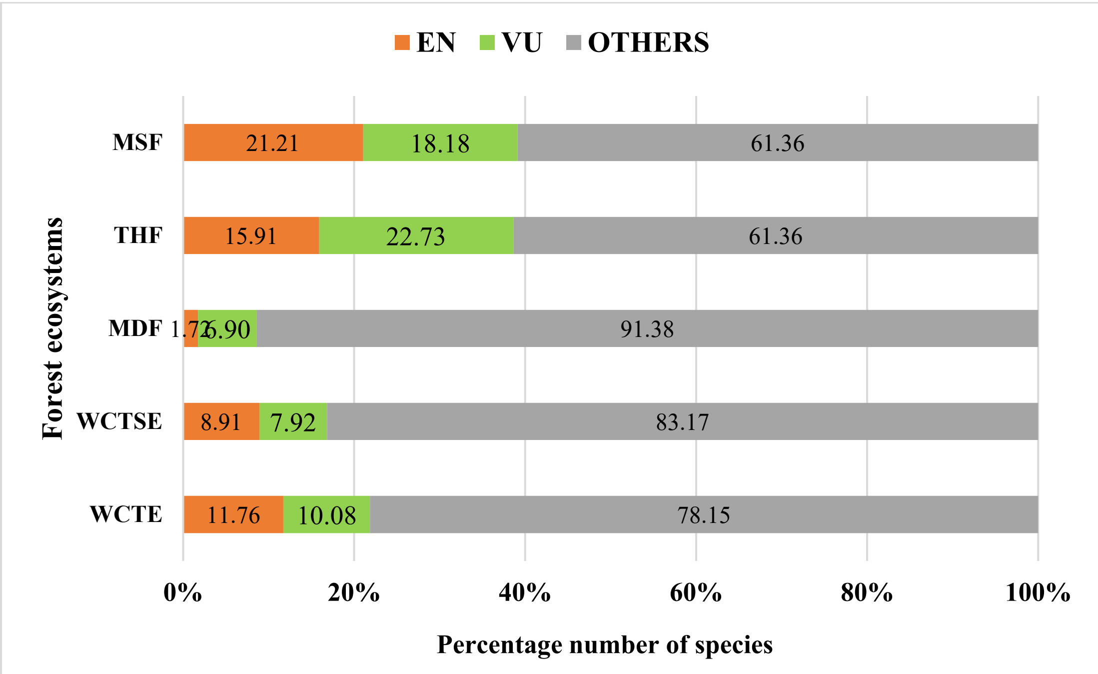


Figure 43. Proportional composition of Endangered (EN) and Vulnarable (VU) species in all the forest ecosystems

4.1.6. Percentage composition of endemic trees in all the ecosystems

Species composition based on endemism was estimated for the total number of individual species. Myristica swamp forest constituted the more significant proportion of 85.44 percent of endemism, followed by tropical hilltop forest (78.15 %), tropical evergreen forest (55.58 %), and the lowest (29.26 %) recorded for moist deciduous (Figure 42). Similarly, on account of the total number of individuals, the greater percentage of endemism (63.64 %) for tropical hilltop forest followed by myristica swamp forest (60.61 %) (Figure 44).

4.1.7. Composition of threatened tree species in all the forest types

From all the forest types, the number of tree species belonging to the threatened and vulnerable categories is higher in the myristica swamp forest (EN= 21.21), followed by tropical hilltop forest (EN= 15.91) and (EN=11.76) and tropical evergreen. The percentage of species vulnerable to extinction is higher in the tropical hilltop forest (VU= 22.73), myristica swamp forest (VU= 18.18), and (VU= 10.08) for tropical wet evergreen forest (figure 43).

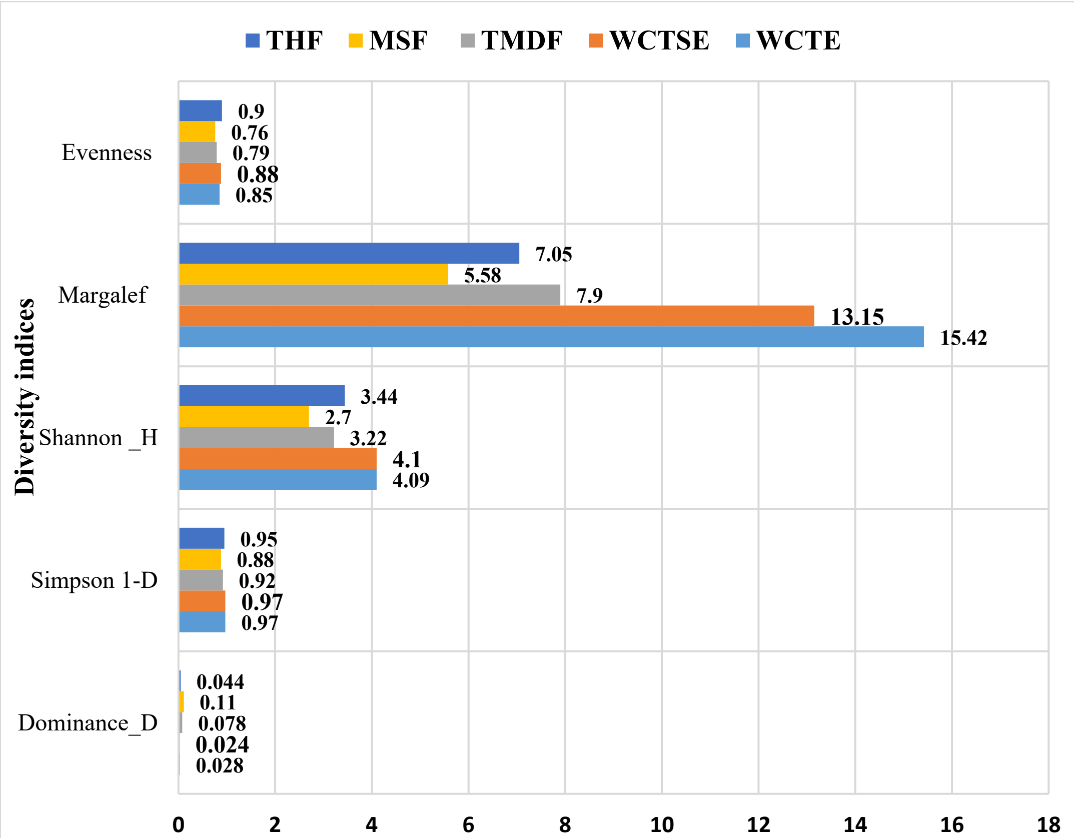
4.1.8. Floristic diversity in forest ecosystems of Shendurney Wildlife Sanctuary

Diversity indices of all the forest types was calculated using the PAST (PAleontological STatistics) software. The details of all the values of diversity indices were given in table 36. For all the ecosystems, the diversity indices was calculated and compared. The highest Simpson's index of 0.98 was recorded for WCTSEF, followed by WCTEF (0.97), THF (0.96), SSMDF 0.92, and lowest was recorded for MSF (0.88), respectively. A similar value of Shannon and Weaner's was recorded for WCTEF (4.10) and WCTSEF, followed by 3.44 for THF. The lowest value, 2.70, was recorded for MSF. The species evenness was recorded highest (0.90) for THF followed by 0.85 for WCTSE and the lowest 0.76 for MSF. The WCTEF showed the higher value of the Margalef index of 15.42, followed by 13.15 for WCTSEF and 7.90 for SSMDF. The lowest value of 5.58 was recorded for MSF, respectively (Table 31 and figure 44).

Table 31. Diversity indices of all the forest ecosystems

Diversity Indices	**WCTEF**	**WCTSE**	**SMDF**	**MSF**	**THF**
Dominance_D	0.028	0.024	0.078	0.11	0.044
Simpson 1-D	0.97	0.97	0.92	0.88	0.95
Shannon _H	4.10	4.09	3.22	2.70	3.44
Margalef	15.42	13.15	7.90	5.58	7.05
Evenness	0.85	0.88	0.79	0.76	0.90

(**WCTEF**, West Coast Tropical Evergreen; **WCTSE**, West Coast Tropical Semi-Evergreen; **SMD**, Southern Moist Deciduous; **MSF**, Myristica Swamp Forest; **THF**; Tropical Hilltop Forest)



WCTE; West coast tropical evergreen forest, **WCTSE**; West coast tropical semi-evergreen forest; **TMDF**; Tropical moist deciduous forest, **MSF;** Myristica Swamp forest, **THF**; Tropical hilltop forest

Figure 44. Diversity indices of all the forest ecosystems

4.1.9. Density and Basal area of the species

The density and basal area per hectare vary across all the forest ecosystems. The highest density, 1144 ha^{-1} was recorded for the myristica swamp forest, followed by 1053.50 ha^{-1} for the tropical wet evergreen forest, 914.55 ha^{-1} for the tropical semi-evergreen forest, and the lowest density 619.00 ha^{-1} recorded for tropical hilltop forest (Table 32). The highest basal area per hectare, 50.04 m^2 ha^{-1} was recorded for the tropical wet evergreen forest, followed by 41.64 m^2 ha^{-1} for tropical semi-evergreen forest and 33.93 m^2 ha^{-1} for myristica swamp forest, and the lowest 16.93 m^2 ha^{-1} for tropical hilltop forest (Table 32).

Table 32. Tree species density and basal area of forest ecosystems

Forest Types	**Density (ha^{-1})**	**Basal Area (m^2 ha)**
WCTE	1053.50	50.04
WCTSE	914.55	41.64
SMDF	876.97	26.88
MSF	1144.44	33.93
THF	619.00	16.93

(**WCTE**, West Coast Tropical Evergreen; **WCTSE**, West Coast Tropical Semi-Evergreen; **SMD**, Southern Moist Deciduous; **MSF**, Myristica Swamp Forest; **THF**; Tropical Hilltop Forest).

4.1.10. Similarity index

The similarities between communities were estimated using Sorenson's similarity index. The highest similarity, 0.38, was found between the west coast tropical evergreen and semi-evergreen forest, followed by 0.29 between tropical semi-evergreen and southern secondary moist deciduous forest. The similarity between the west coast tropical evergreen forest and tropical hilltop forest was found to be 0.27.

4.2. Soil studies

4.2.1. Physicochemical Soil Properties

4.2.1.1. Soil cation exchange capacity (CEC)

The soil cation exchange capacity obtained from the depth-wise comparison from the analysis of variance revealed no notable difference in cation exchange capacity at 10-30 cm and 30-60 cm depth. The maximum (7.58 cmol (+) kg^{1}) depth-wise value of CEC was recorded at 0-10 cm depth, whereas the lowest (4.71 cmol (+) kg^{1}) value was recorded for the 60-100 depth (Table 38). The result demonstrated that there was a subsequent reduction in soil cation exchange capacity down the profile.

The comparison of soil cation exchange capacity (CEC) from the analysis of variance based on the forest ecosystems and depths interaction revealed a significant difference across the forest ecosystem types at different soil depth levels (Table 37). At 0-10 cm depth, there was a significant difference across all the forest ecosystems types with a maximum (12.25 cmol (+) Kg^{1}) cation exchange capacity observed in the tropical hilltop forest followed by west coast tropical evergreen forest (7.87 cmol(+)Kg^{1}) whereas the lowest (4.54 cmol(+)Kg^{1}) value was observed for myristica swamp forest. The result showed no significant difference in soil CEC at 10-30 cm depth level for west coast tropical semi-evergreen and west tropical evergreen forest while significant difference was demonstrated in the other forest ecosystems with maximum (6.30 cmol (+)Kg^{1}) recorded for tropical hilltop forest and lowest (4.16 cmol(+)Kg^{1}) for myristica swamp forest.

At 30-60 cm depths, the CEC showed significant difference across the forest types, with tropical hilltop forest having the highest value of CEC (5.86 cmol (+) Kg^{1}) followed by west coast tropical semi-evergreen forest (5.61 cmol (+) Kg^{1}) whereas the lowest value (4.03 cmol (+) Kg^{1}) was recorded for myristica swamp forest. At 60-100 cm depth, there was no significant difference in soil CEC between southern moist mixed deciduous forest and tropical hilltop forest, whereas in the other forest ecosystems, the result showed a significant difference with the highest value (5.71 cmol(+)Kg^{1}) recorded for the west coast tropical semi-evergreen and lowest (3.73 cmol(+)Kg[1]) was observed for myristica swamp forest. The overall mean value of cation exchange capacity for all the forest types across all soil depths was represented in table 32 and fig. 45.

The result of the correlation coefficient showed that in west coast tropical semi-evergreen forest, the cation exchange capacity positively correlated with percent organic where r=0.448, pH where r= 0.450, electrical conductivity where r= 0.562 whereas negatively correlated with bulk density where r= -0.435. Similarly, in the west coast tropical evergreen forest, the cation exchange capacity positively correlated with percent organic carbon where r=0.899 and significantly correlated with all the pH (r= 0.768, p< 0.01) and electrical conductivity (r= 0.915, p< 0.01) while negatively correlated with bulk density (r=-0.624). In the southern moist mixed deciduous forest, there was a significant correlation between the cation exchange capacity positively correlated with organic carbon (r=0.891, p<0.01) and pH (r=0.586, p< 0.05), and negatively correlated with bulk density (r=-0.402). In myristica swamp forest, cation exchange capacity showed a significant correlation with percent organic carbon (r= 0.691, p <0.05) and electrical conductivity (r= 0.659, p<0.05) and negatively correlated with pH (r=-117), and bulk density (r=-0.426). In the tropical hilltop forest cation exchange capacity significantly correlated with percent organic carbon (r=0.841, p<0.01) and electrical conductivity (r=0.886, p<0.01), and positively correlated with pH (r=0.503). However, a significant negative correlation with the bulk density (r=-0.802, p<0.01) was observed (Table 40 to 44). This result indicated that, except in the myristica swamp forest where cation exchange capacity negatively correlated with soil pH, soil with higher cation exchange capacity would have higher percent organic carbon, pH, electrical conductivity, and lower bulk density.

Table 33. Soil Cations Exchange Capacity (cmol kg^{-1}) (CEC)

Cations Exchange Capacity (cmol kg^{-1}) Mean± SD				
Forest Types	**0-10cm**	**10-30 cm**	**30-60cm**	**60 -100cm**
WCTSE	6.33±0.08	5.72±0.09	5.61± 0.09	5.71± 0.50
WCTE	7.87±0.10	6.08±0.27	5.55± 0.48	4.79±0.30
SMDF	6.91±0.40	5.21±0.14	4.85±0.12	4.65± 0.15
MSWP	4.54±0.07	4.16±0.23	4.03±0.26	3.73 ±0.08
THF	12.25±052	6.30±0.29	5.86±0.50	4.68±0.08
CD for the interaction = 0.82				

WCTE= West Coast Tropical Evergreen, **WCTSE**=West coast tropical semi-evergreen, **SMDF**= Southern Moist Mixed Deciduous Forest, **MSF**= Myristica Swamp, **THF**= Tropical Hilltop Forest

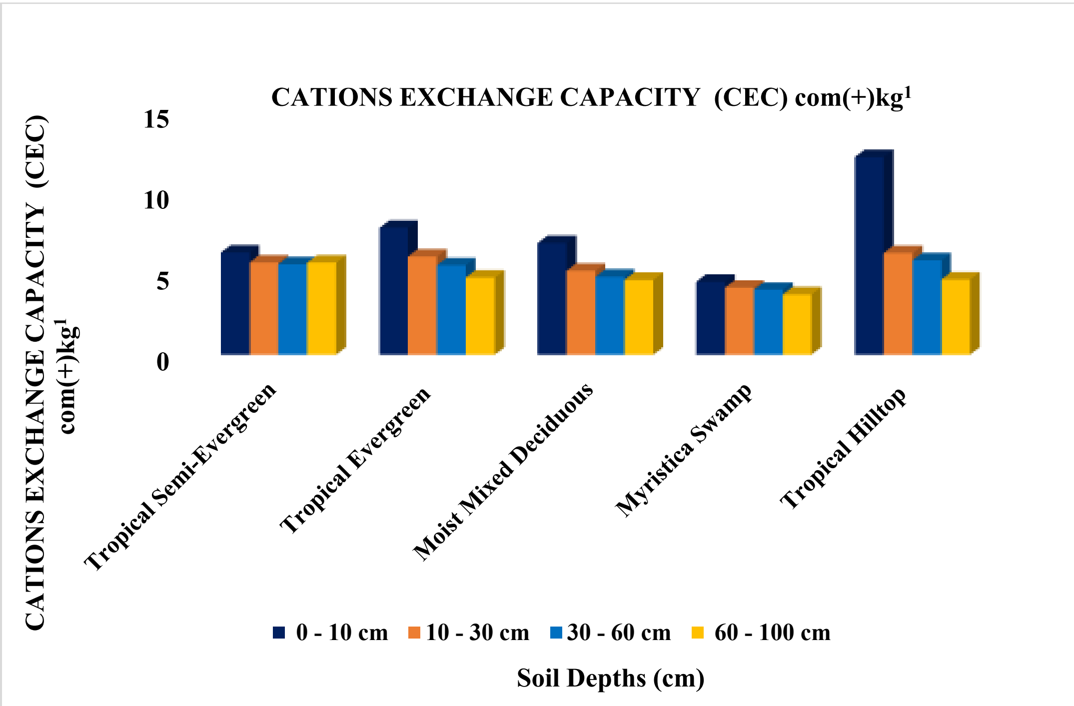


Figure 45. Soil cation exchange capacity (CEC) at different depths levels for all the ecosystems

4.2.1.2. Soil organic carbon (%)

The result of soil percent organic carbon obtained from the analysis of variance for the depth-wise comparison indicated a significant difference across the four different depths levels (Table 38). The highest (1.94%) percent organic carbon was manifested for 0-10 cm depth. The subsequent reduction in the percent organic carbon down the profile was observed. The lowest (0.78%) percent organic carbon was recorded at the 60-100cm depth.

The result of the comparison of soil percent organic carbon for the interaction between the forest ecosystem types and soil depth level is presented in table 37. The result revealed a significant difference in the percent organic carbon at 0-10 cm depth for all the forest ecosystem types. The value was significantly highest (2.87%) for tropical hilltop forest followed by (2.58%) west coast tropical evergreen forest, whereas the least (1.04%) was recorded for the moist mixed deciduous forest. A similar trend was observed at 10-20cm depth, with the percent organic carbon significantly differs among all the forest ecosystem types with the higher value (2.39%) recorded for the tropical hilltop forest followed by (1.89 %) west coast tropical semi-evergreen whereas the lowest value (0.69%) was observed for myristica swamp forest. At 30-60 cm depth, the percent organic carbon showed no significant difference between southern moist mixed deciduous and myristica swamp forest, the higher value (1.46 %) was observed for west coast tropical evergreen whereas the least (0.61%) value was recorded for west coast tropical semi-evergreen (Table 33). There is no significant difference at 60-100cm depth level between the west coast tropical semi-evergreen, moist mixed deciduous, and the myristica swamp forest, the highest (1.11 %) value was recorded for west coast tropical evergreen forest (table 34 and figure 46).

The result of the correlation coefficient affirmed that in west coast tropical semi-evergreen, the percent organic carbon positively correlated with cation exchange capacity (r=0.448), significantly correlated with the pH (r=0.825, p< 0.01), electrical conductivity (r=0.890, p< 0.01), and negatively correlated with bulk density (r=-0.679, p< 0.05). In west coast tropical evergreen forest, there was a positive correlation between the percent organic carbon and cation exchange capacity (r=0.899), significantly with pH (r=0.690, p<0.05), electrical conductivity (r=0.966, p< 0.01), while significantly and negatively correlated with bulk density (r=-0.813, p< 0.01). In the moist mixed deciduous forest, percent organic carbon significantly correlated with cation exchange capacity (r=0.891, p< 0.01), positively correlated pH (r=0.557), electrical conductivity (r=0.255), whereas significantly and negatively correlated with bulk density (r=-0.625, p< 0.05). In myristica swamp forest, percent organic carbon correlated significantly with cation exchange capacity (r=0.691, p< 0.05), electrical conductivity (r=0.953, p< 0.01), and negatively correlated with pH (r=-0.298) and bulk density (r=-0.513). In tropical hilltop forest, organic carbon correlated positively with pH (r=0.503), significantly with cation exchange capacity (r=0.841, p< 0.01), electrical conductivity (r=0.952, p< 0.01) while significantly and negatively correlated with bulk density (r=-0.902, p< 0.01) (Table 40 to 44). This result indicated that except for myristica swamp forest, where percent organic carbon negatively correlated with pH, for all the ecosystem soil with higher percent organic carbon would have a higher value of pH, cation exchange capacity, electrical conductivity, and lower bulk density.

Table 34. Soil percent organic carbon at different depths levels in different ecosystems

Soil organic carbon (%) Mean± SD				
Forest Types	**0 -10 cm**	**10-30 cm**	**30-60 cm**	**60 -100 cm**
WCTSE	1.87± 0.09	1.57±0.05	0.61±0.03	0.47±0.01
WCTE	2.58±0.05	1.89±0.01	1.46±0.03	1.11±0.05
SMDF	1.04±0.01	0.73±0.04	0.66± 0.03	0.56±0.03
MSWP	1.33 ±0.10	0.69±0.01	0.63±0.03	0.46±0.03
THF	2.87±0.20	2.39±0.02	1.37±0.05	0.74±0.03
CD for the interaction =0.17				

WCTSE=West coast tropical semi evergreen**, WCTE=** West Coast Tropical Evergreen**, MMDF=** Moist Mixed Deciduous Forest**, MSWP**= Myristica Swamp**, THF=** Tropical Hilltop Forest

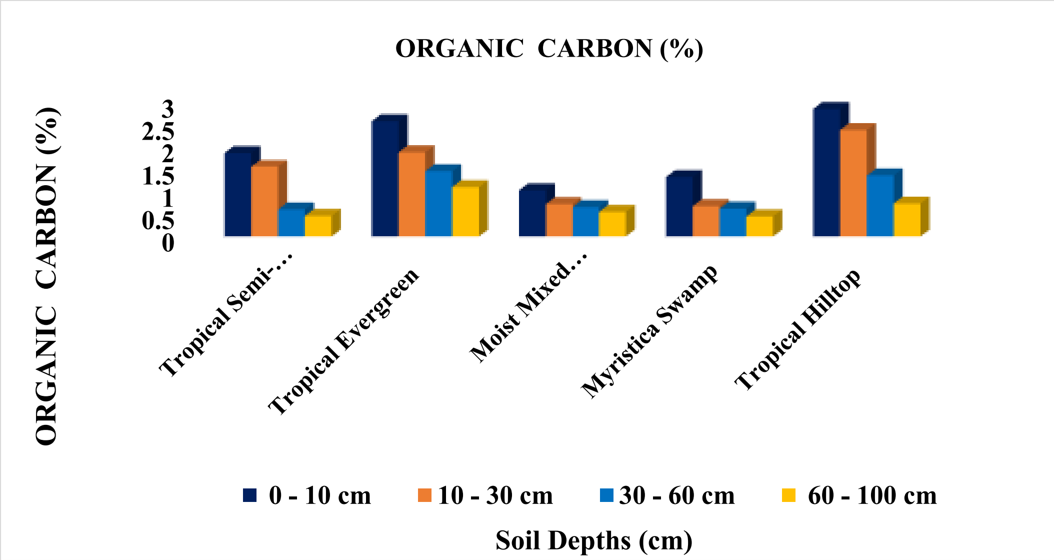


Figure 46. Soil percent organic carbon at different depths levels in different ecosystems

4.2.1.3. Soil electrical conductivity

The result from the analysis of variance of soil electrical conductivity is represented in Tab. 33 and Fig. 48. The depth-wise comparison of the soil electrical conductivity between the different soil depths showed no significant difference between 10-30cm depth and 30-60 cm depths. The highest value (0.48 dSm^{-1}) of soil electrical conductivity was observed at 0-10 cm depth, whereas the lowest (0.13 dSm^{-1}) value was recorded at the 60-100 cm depth (Table 37).

The result from the comparison of soil electrical conductivity for the interaction between the forest ecosystems types and each soil depth level is represented in Table 36. The result affirmed no significant difference in the soil electrical conductivity at 0-10 cm depth for west coast tropical semi-evergreen and moist mixed deciduous forest, whereas the significant difference was observed for the other forest ecosystem types. The highest value (0.93 dSm^{-1}) of electrical conductivity was recorded for the tropical hilltop forest. At the 10-30 cm soil depths, there was no significant difference between the southern moist mixed deciduous forest and myristica swamp forest. The highest (0.64 dSm^{-1}) value was recorded for tropical hilltop forest, whereas the lowest (0.12dSm-1) value was recorded for the myristica swamp forest. At 30-60 cm, soil depth showed no significant difference between west coast tropical semi-evergreen and myristica swamp, with the highest value (0.46 dSm^{-1}) recorded for the moist mixed deciduous forest. At 60-100 cm depth, the electrical conductivity result showed no significant difference between west coast tropical semi-evergreen, moist mixed deciduous, and myristica swamp forest. In contrast, a significant difference was recorded for the other forest ecosystem types (Tab. 33 and fig. 47). The highest (0.23 dSm^{-1}) value of electrical conductivity was recorded for tropical hilltop forests.

The result of the correlation coefficient demonstrated that, in west coast tropical semi-evergreen forest, electrical conductivity was positively correlated with cation exchange capacity (r=0.562), significantly correlated with percent organic carbon (r=0.890, p< 0.01) and pH (r=0.639, p< 0.05) while significantly and negatively correlated with bulk density (r=-0.634, p< 0.05). In west coast tropical evergreen forest the electrical conductivity significantly correlated with cation exchange capacity (r=0.915, p< 0.01), percent organic carbon (r=0.966, p< 0.01), pH (r=0.797, p< 0.01) and negatively correlated with bulk density (r=-0.699). In the moist mixed deciduous forest, electrical conductivity positively correlated with cation exchange capacity (r=0.137), organic carbon (r=0.255), and negatively correlated pH (r=-0.635), and bulk density (r=-0.314). In the myristica swamp forest, the electrical conductivity correlated significantly with cation exchange capacity (r=0.659, p< 0.05), percent organic carbon (r=0.953, p< 0.01) while negatively correlated with pH (r=-0.436) and bulk density (r=-0.555).

In tropical hilltop forest, there was a significant correlation between electrical conductivity and cation exchange capacity (r=0.886, p< 0.01), percent organic carbon (r=0.952, p< 0.01), positively correlated with pH (r=0.570) while significantly and negatively correlated with bulk density (r=-0.946, p< 0.01) (Table 40 to 44). This result depicted that in the west coast tropical semi-evergreen, west coast tropical evergreen, and tropical hilltop forest, the higher the electrical conductivity value, the higher the cation exchange capacity, percent organic carbon, and pH while the lower the bulk density. Contrarily, the pH value showed an inverse relationship with electrical conductivity in the moist deciduous and myristica swamp forest.

Table 35. Soil electrical conductivity at different depth levels in different ecosystems

Electrical conductivity (dSm^{-1}) Mean± SD				
Forest Types	**0 -10cm**	**10-30 cm**	**30-60cm**	**60 -100cm**
WCTSE	0.27 ± 0.02	0.17±0.004	0.13±0.003	0.09 ±0.04
WCTE	0.56 ± 0.01	0.26±0.020	0.19±0.03	0.13±0.02
SMDF	0.28±0.01	0.12±0.001	0.46±0.04	0.08±0.001
MSWP	0.37 ±0.01	0.12±0.002	0.14±0.01	0.10±0.002
THF	0.93±0.02	0.64±0.020	0.33 ±0.01	0.22±0.01
CD for the interaction = 0.04				

WCTSE=West coast tropical Semi-evergreen, **WCTE**= West Coast Tropical Evergreen, **MMDF**= Moist Mixed Deciduous Forest, **MSWP**= Myristica Swamp, **THF**= Tropical Hilltop Forest

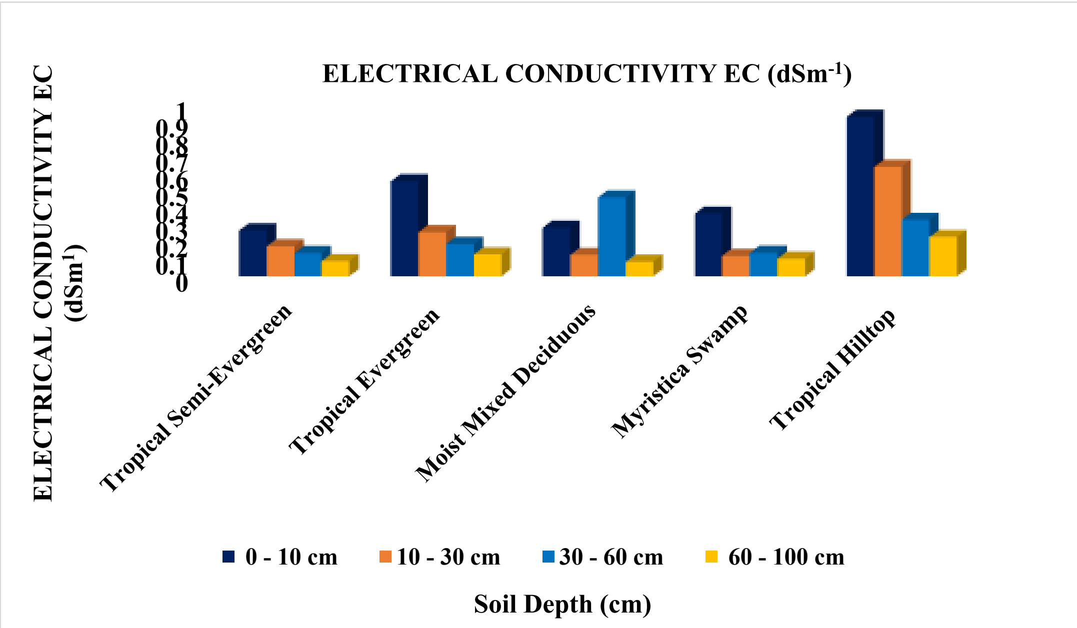


Figure 47. Soil electrical conductivity at different depths levels in different ecosystems

4.2.1.4. Bulk density

The result of the depth-wise interaction for soil bulk density obtained from the analysis of variance for the four different depths demonstrated a significant difference across the depths levels. The highest average value (1.59 gcm^{-3}) of bulk density was observed for the 60-100 cm depth followed by the 30-60 cm depth, whereas the least value (1.26 gcm^{-3}) was recorded for the 0-10 cm depth (Table 39).

The comparison of soil bulk density for the interaction between the depths and forest ecosystems types is represented in Tab. 36 and Fig. 48. The association of the bulk density with all the forest ecosystem types at 0-10 cm depth affirmed that there is no significant difference in bulk density between the west coast tropical semi-evergreen and west coast tropical evergreen forest with the highest value (1.61 gcm^{-3}) observed for myristica swamp whereas the lowest (0.96 gcm^{-3}) observed for tropical hilltop forest. At 10-30 cm depth, the bulk density significantly differs across all the forest ecosystem types, with the highest value (1.75 gcm^{-3}) observed for myristica swamp, whereas the lowest (1.11 gcm^{-3}) was observed for Tropical hilltop forest. Similarly, at 30-60 cm depth, the bulk density significantly differs across all the forest ecosystem types with the higher value (1.83 gcm^{-3}) was recorded for myristica swamp, whereas the lowest (1.23 gcm^{-3}) was observed for west coast tropical evergreen forest. Across all the ecosystems, bulk density showed there is no significant difference between the West coast tropical evergreen and tropical hilltop forest at 60-100 cm depth. The highest (1.87 gcm^{-3}) of bulk density was recorded for myristica swamp forest, whereas the lowest (1.42 gcm^{-3}) value is manifested in the west coast tropical evergreen forest.

The result of the correlation coefficient showed that, in west coast tropical semi-evergreen, bulk density negatively correlated with all the soil properties viz. (r=-0.435) for cation exchange capacity, (r=-0.679, $p< 0.05$) for percent organic carbon, (r=-0.596, $p< 0.05$) for pH, and (r=-0.634, $p< 0.05$) for electrical conductivity. In west coast tropical evergreen forest, bulk density negatively correlated with cation exchange capacity (r=-0.624), pH (r=-0.346), and electrical conductivity while significantly correlated with percent organic carbon (r=-0.813, *p*< 0.01). Bulk density negatively correlated with cation exchange capacity (*r*=-0.402), pH (*r*=-0.240), electrical conductivity (*r*=-0.314), and significantly and negatively correlated with percent organic carbon (*r*=-0.625, *p*<0.05) for the moist mixed deciduous forest. In the myristica swamp forest, bulk density negatively correlated with cation exchange capacity (*r*=-0.426), for percent organic carbon (*r*=-0.513), electrical conductivity (*r*=-0.555) while positively correlated with pH (*r*=0.223). In tropical hilltop forest, there is a significant negative correlation between the bulk density and cation exchange capacity (*r*=-0.802, *p*<0.01), percent organic carbon (*r*=-0.902, *p*<0.01), and electrical conductivity (*r*=-0.946, *p*<0.01) and negatively correlated with pH (*r*=-0.508) (Table 40 to 44). This result showed that, except in the myristica swamp forest, where bulk density positively correlated with soil pH, for all the other ecosystems, bulk density negatively correlated with all the other properties for all the ecosystems.

Table 36. Bulk density at different depth levels for all the ecosystems

Bulk density (gcm^{-3}) Mean± SD				
Forest Types	**0 -10cm**	**10-30 cm**	**30-60cm**	**60 -100cm**
WCTSE	1.23± 0.07	1.40± 0.08	1.47± 0.09	1.50±0.05
WCTE	1.15±0.01	1.17± 0.02	1.23±0.04	1.42±0.03
MMDF	1.38±0.11	1.43 ± 0.03	1.51 ±0.10	1.68±0.06
MSWP	1.61 ±0.11	1.75±0.120	1.83±0.02	1.87±0.01
THF	0.96±0.05	1.11±0.010	1.38±0.06	1.46±0.05
CD for the interaction =0.19				

WCTSE=West coast tropical semi-evergreen**, WCTE=** West Coast Tropical Evergreen**, MMDF=** Moist Mixed Deciduous Forest**, MSWP**= Myristica Swamp**, THF=** Tropical Hilltop Forest

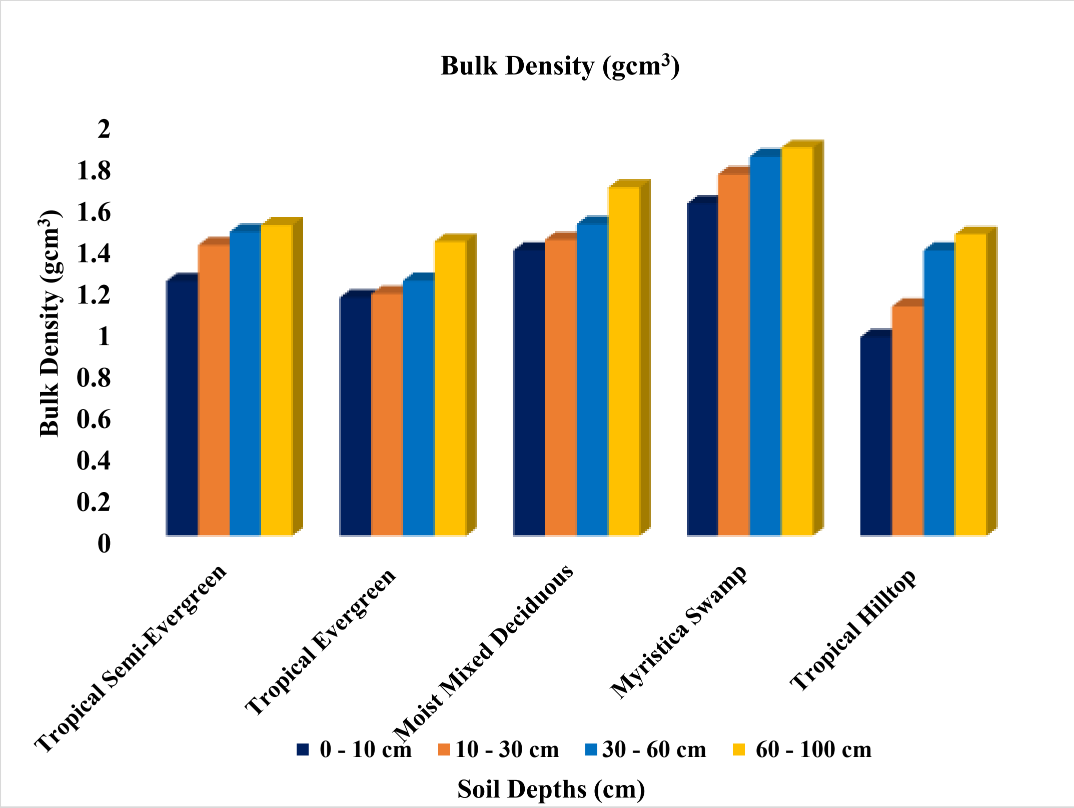


Figure 48. Bulk density at different depth levels for all the ecosystems

4.2.1.5. Soil pH

The analysis of variance showed that the depth-wise comparison between the different soil depths levels was not significant for the 0-10 cm and 10-30 cm depth, respectively. The highest (5.53) soil pH value was observed at 0-10 cm depth, whereas the least (5.14) was recorded at the 60-100 cm depth. The soil pH value of all the different depths was presented in (table 39). The pH values of soil from all the forest types were found to be slightly acidic.

The result obtained for the comparison of the interaction between the forest ecosystem types and soil depths for the soil pH showed there is a significant difference across all the ecosystems. The comparison among all the forest types at 0-10 cm depth showed the pH value was not significantly different between the tropical semi-evergreen and myristica swamp forest, with the highest (5.53) value of pH recorded for the moist mixed deciduous forest. At 10-30 cm depth, there was no significant difference between the tropical semi-evergreen and tropical hilltop forest. The highest (5.69) soil pH value was observed for the moist mixed deciduous forest. The soil pH value at 30-60 cm depth significantly varied across all forest ecosystem types.

The highest (5.40) soil pH was observed for the myristica swamp forest, whereas the lowest (4.90) pH was recorded for the moist mixed deciduous forest. Similarly, at the 60-100 cm depth, the soil pH value showed significant difference across all the forest ecosystem types with the highest (5.59) soil pH value recorded for moist mixed deciduous followed by (5.48) for myristica swamp forest whereas the lowest (5.00) soil pH was recorded for tropical hilltop forest respectively (Table 37).

The result of the correlation coefficient showed that soil pH positively correlated with the cation exchange capacity (r=0.450) and significantly correlated with percent organic carbon (r=0.825, p<0.01), electrical conductivity (r=0.639, p<0.05), and significantly and negatively correlated with bulk density (r=-0.596, p<0.05) in west coast tropical semi-evergreen. In west coast tropical evergreen forest, pH value significantly correlated with cation exchange capacity (r=0.768, p<0.01), electrical conductivity (r=0.797, p<0.01), and percent organic carbon (r=0.640, p<0.05) while negatively correlated with bulk density (r=-0.346). In the moist mixed deciduous forest, pH value significantly correlated with cation exchange capacity (r=0.586, p<0.05) and positively correlated with percent organic carbon (r=0.557) while negatively correlated with electrical conductivity (r=-0.635), and bulk density (r=-0.240). The pH value showed a negative correlation with cation exchange capacity (r=-0.117), percent organic carbon (r=-0.298), and electrical conductivity (r=-0.436), whereas positively correlated with bulk density(r=0.223) in the myristica swamp forest. In tropical hilltop forest, pH value showed a positive correlation with cation exchange capacity (r=0.503), electrical conductivity (r=0.570), and percent organic carbon (r=0.503) while negatively correlated with bulk density (r=0.508) (Table 40 to 44).

Table 37. Soil pH at different depth levels for all the ecosystems

Soil pH Mean± SD				
Forest Types	**0-10cm**	**10-30 cm**	**30-60cm**	**60 -100cm**
WCTSE	5.40 ± 0.01	5.43±0.01	5.28 ±0.04	5.28±0.03
WCTE	5.47±0.09	5.16±0.02	5.10±0.06	5.16±0.06
SMDF	5.53± 0.08	5.69±0.05	4.91±0.01	5.59 ±0.03
MSWP	5.39±0.023	5.67±0.06	5.40±0.04	5.48±0.05
THF	5.44±0.08	5.14±0.36	5.04±0.02	5.00±0.01
CD for the interaction =0.27				

WCTSE=West coast tropical Semi-evergreen, **WCTE**= West Coast Tropical Evergreen, **MMDF**= Moist Mixed Deciduous Forest, **MSWP**= Myristica Swamp, **THF**= Tropical Hilltop Forest

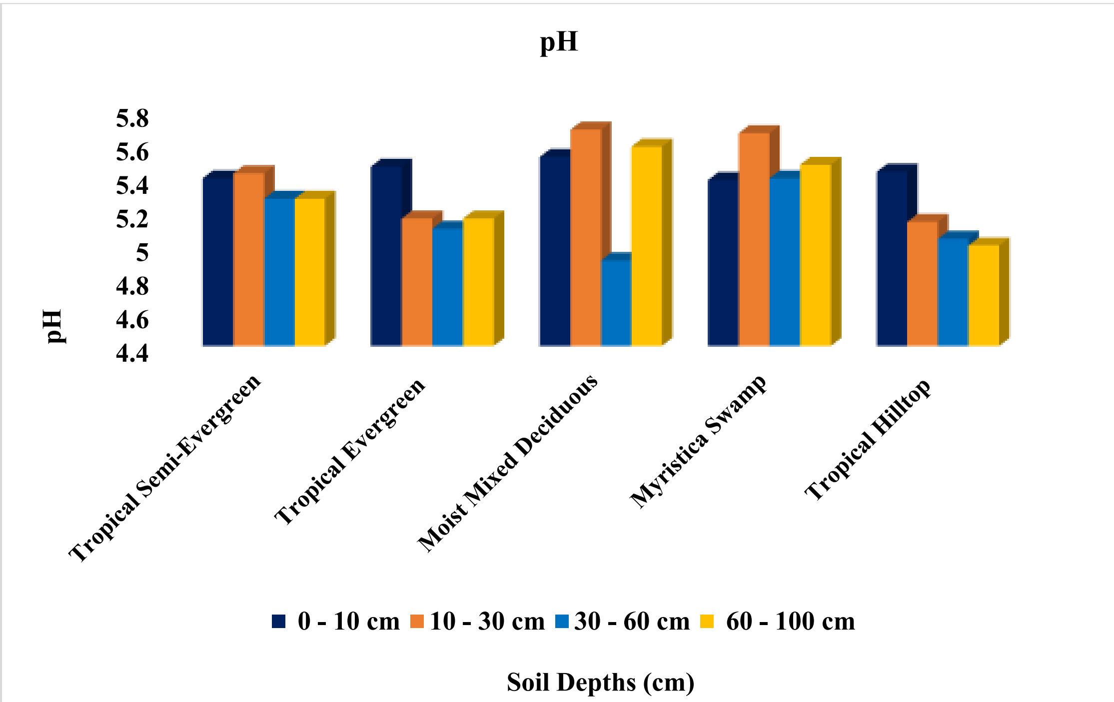


Figure 49. Soil pH at different depth levels for all the forest ecosystems

Table 38. The overall mean value of physicochemical properties of the soil across the forest types over all the depths level

Forest types	CEC cmol (+)Kg^{-1}	OC (%)	EC (dSm^{-1})	BD (gcm^{-3})	PH
WCTSE	5.84^{b}	1.13^{c}	0.17^{d}	1.40^{c}	5.34^{b}
WCTE	6.07^{b}	1.76^{b}	0.28^{b}	1.24^{d}	5.22^{bc}
SMDF	5.40^{c}	0.75^{d}	0.24^{c}	1.50^{b}	5.53^{a}
MSF	4.11^{d}	0.78^{d}	0.18^{d}	1.76^{a}	5.49^{a}
THF	7.27^{a}	1.98^{a}	0.53^{a}	1.23^{d}	5.16^{c}
CD	**0.41**	**0.09**	**0.02**	**0.10**	**0.13**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

Table 39. The average physicochemical properties of the soil across the forest types over all the depths level

Soil Depth (cm)	CEC Cmol(+)Kg^{-1}	OC (%)	EC (dSm^{-1})	BD (gcm^{-3})	PH
0-10	7.58^{a}	1.94^{a}	0.48^{a}	1.27^{d}	5.53^{a}
10-30	5.49^{b}	1.45^{b}	0.26^{b}	1.37^{c}	5.42^{ab}
30-60	5.18^{b}	0.95^{c}	0.25^{b}	1.48^{b}	5.30^{b}
60-100	4.71^{c}	0.78^{d}	0.13^{c}	1.59^{a}	5.14^{c}
CD	**0.37**	**0.08**	**0.02**	**0.09**	**0.12**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

Table 40. The correlations matrix of soil physicochemical properties in west coast tropical evergreen

	CEC	OC	pH	EC	BD
CEC	**1**				
OC	.899	**1**			
pH	.768**	.690*	**1**		
EC	.915**	.966**	.797**	**1**	
BD	-624	-.813**	-346	-.699	**1**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

**. Correlation is significant at the 0.01 level (2tailed)

*. Correlation is significant at the 0.05 level (2tailed)

Table 41. The correlations matrix of soil physicochemical properties in west coast tropical semi-evergreen

	CEC	OC	pH	EC	BD
CEC	**1**				
OC	.448	**1**			
pH	.450	.825**	**1**		
EC	.562	.890**	.639*	**1**	
BD	-.435	-.679*	-.596*	-.634*	**1**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

****.** Correlation is significant at the 0.01 level (2tailed)

***.** Correlation is significant at the 0.05 level (2tailed)

Table 42. The correlations matrix of soil physicochemical properties in moist mixed deciduous forest

	CEC	OC	pH	EC	BD
CEC	**1**				
OC	.891**	**1**			
pH	.586*	.557	**1**		
EC	.137	.255	-.635	**1**	
BD	-.402	-625*	-.240	-.314	**1**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

****.** Correlation is significant at the 0.01 level (2tailed)

***.** Correlation is significant at the 0.05 level (2tailed)

Table 43. The correlations matrix of soil physicochemical properties in myristica swamp forest

	CEC	OC	pH	EC	BD
CEC	**1**				
OC	.691*	**1**			
pH	-.117	-.298	**1**		
EC	.659*	.953**	-.436	**1**	
BD	-.426	-513	.223	-.555	**1**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

****.** Correlation is significant at the 0.01 level (2tailed)

***.** Correlation is significant at the 0.05 level (2tailed)

Table 44. The correlations coefficient for the association between soil properties in tropical hilltop forest

	CEC	OC	pH	EC	BD
CEC	**1**				
OC	.841**	**1**			
pH	.503	.503	**1**		
EC	.886**	.952**	.570	**1**	
BD	-.802**	-.902**	-.508	-.946**	**1**

pH- Soil pH; **EC**- Electrical Conductivity; **BD**- Bulk Density; **OC**- Percent Organic Carbon; **CEC**- Cation Exchange Capacity

**. Correlation is significant at the 0.01 level (2tailed)

*. Correlation is significant at the 0.05 level (2tailed)

4.3. Forest ecosystems change detection and mapping

The land use and land cover changes of the forest ecosystems of Shendurney Wildlife Sanctuary were studied. A total of six land use and land cover classes (LULC) were established as evergreen forest, semi-evergreen, moist deciduous forest, hilltop forest, degraded forest, and open forest (Table 45). The spatial distribution and the estimates of all the forest cover changes are represented in fig. 61, 62, and table 50. The present study mapped all the forest ecosystems and figured out the extent of their shifts using Landsat-1 and Landsat-8. These findings demonstrated that the west coast tropical evergreen forest occupied the sanctuary's largest size, followed by the secondary moist deciduous forest (table 45 and figure 50). The result indicated that following the seventeenth year's impact, most of the sanctuary area is occupied by a significant proportion of degraded forest followed by west coast tropical evergreen, west coast tropical semi-evergreen, and southern moist deciduous forest (table 45 and figure 50). The insignificant gain in the percentage of west coast evergreen forest was observed from 21.31 % in 2001 to 22.97 % in 2018. Among the different types of forest that had been reduced, the substantial loss was observed in the southern secondary moist deciduous forest; the loss was from 27.11 % in 2001 to 17.23 % in 2018 (table 45 figure 55 and 56), while in the west coast semi-evergreen forest the loss was from 26.91 % in 2001 to 18.98 % in 2018 (table 45 and figure 50). Significant increase in the open forest was observed from 5.89 % in 2001 to 13.21 % in 2018 (figure 9 and 10), whereas southern tropical hilltop forest recorded an increasing degree from 1.45 % in 2001 to 1.96 % in 2018. The extent of degraded forest significantly increased from 14.93

% in 2001 to 23.62 % in 2018. However, nearly 15% of the water body shrunk considerably from 2001 to 2018 (table 45 and figure 50).

Table 45. The area under different forest and other land use of Shendurney wildlife sanctuary from 2001 to 2018

Forests Type	2001 (ha)	%	2018 (ha)	%	Changes
West Coast Trop. Evergreen	3722.02	21.31	4011.61	22.97	289.53
West Coast Trop.Semi-Evergreen	4699.02	26.91	3313.9	18.98	-1385.12
Southern Secondary Moist Deciduous	4735.13	27.11	3008.82	17.23	-1726.3
Southern Trop. Hilltop	253.48	1.45	341.44	1.96	87.96
Open Forest	1028.50	5.89	2306.96	13.21	1278.46
Degraded Forest	2607.97	14.93	4124.51	23.62	1516.55
Water Body	418.05	2.39	356.93	2.04	-61.11
Total	**17464.17**	**100**	**17464.17**	**100**	-

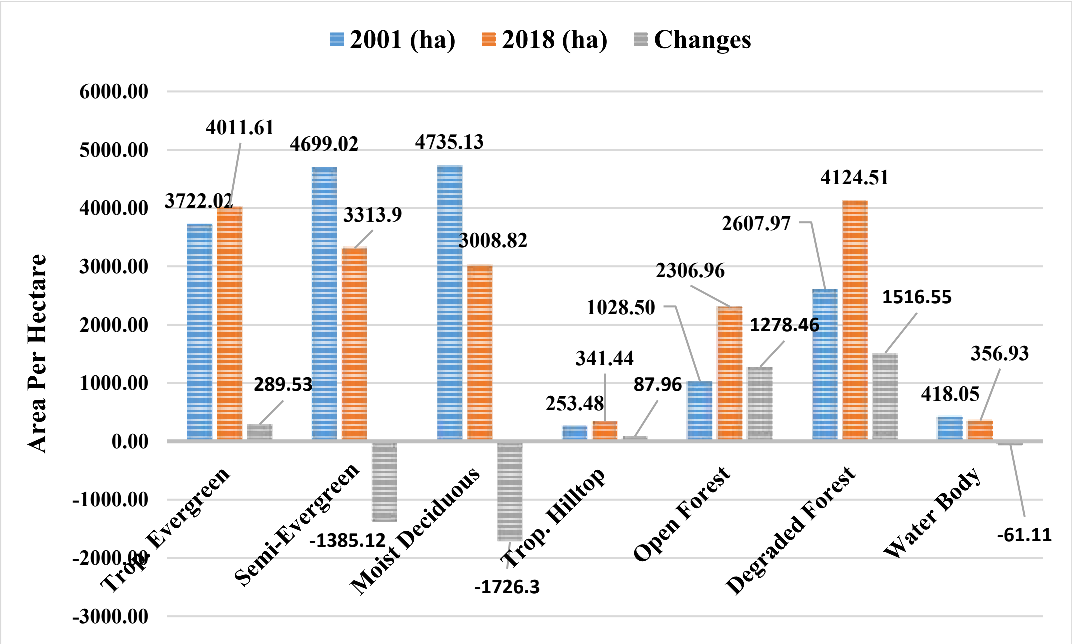


Figure 50.The area under different forest and other land use of Shendurney wildlife sanctuary from 2001 to 2018

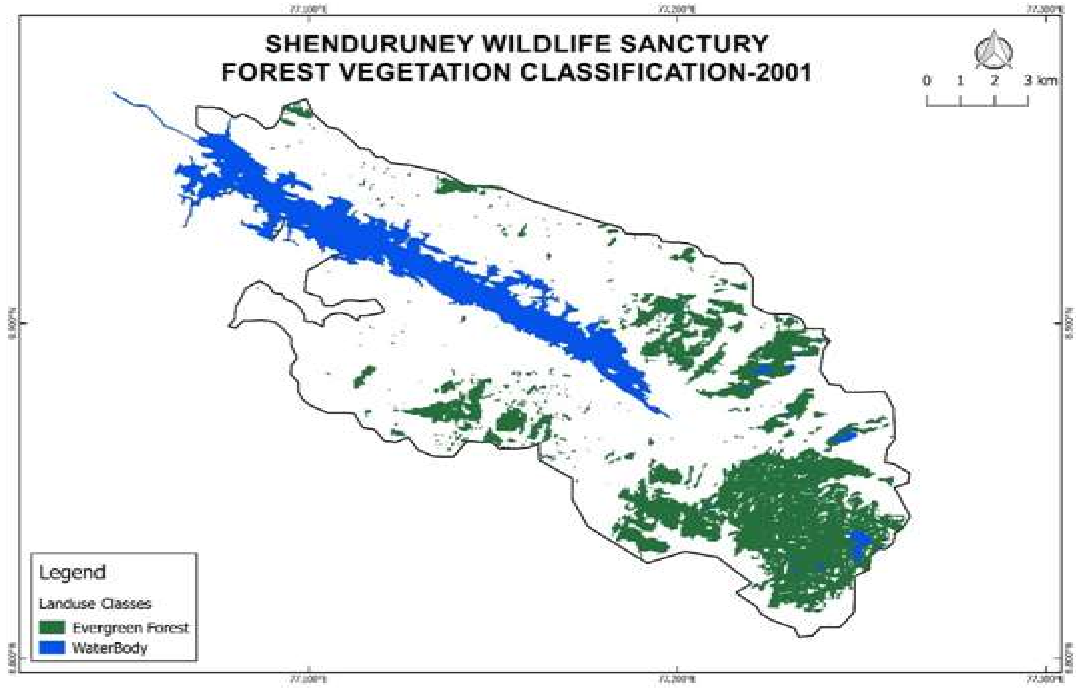


Figure 51. Spatial distribution of evergreen forest vegetation classification 2001

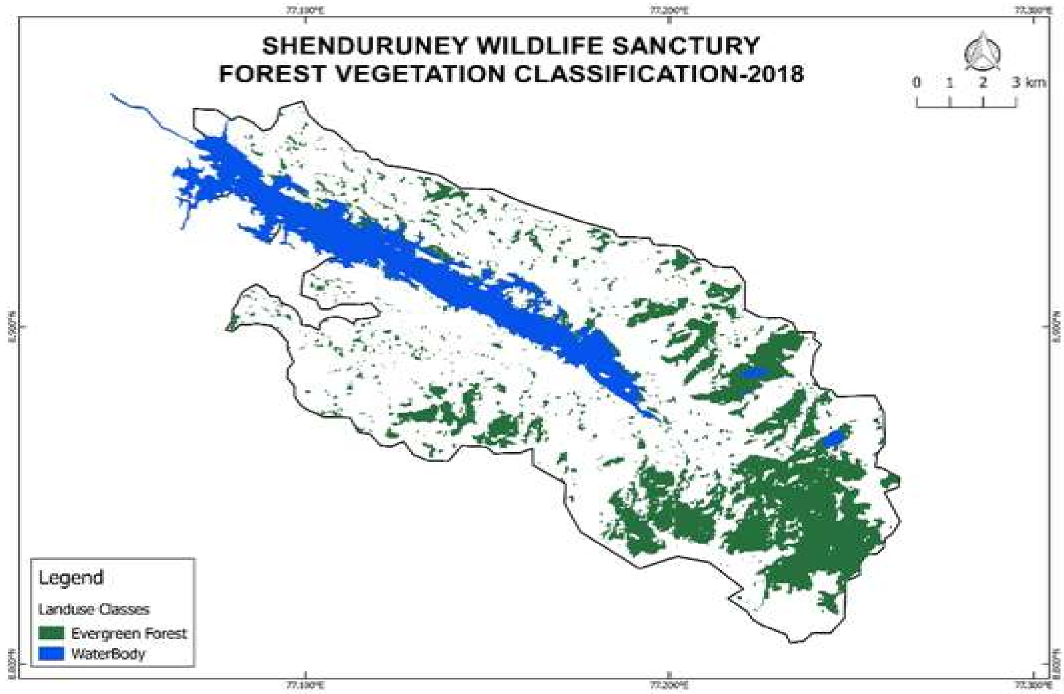


Figure 52. Spatial distribution of evergreen forest vegetation classification 2018

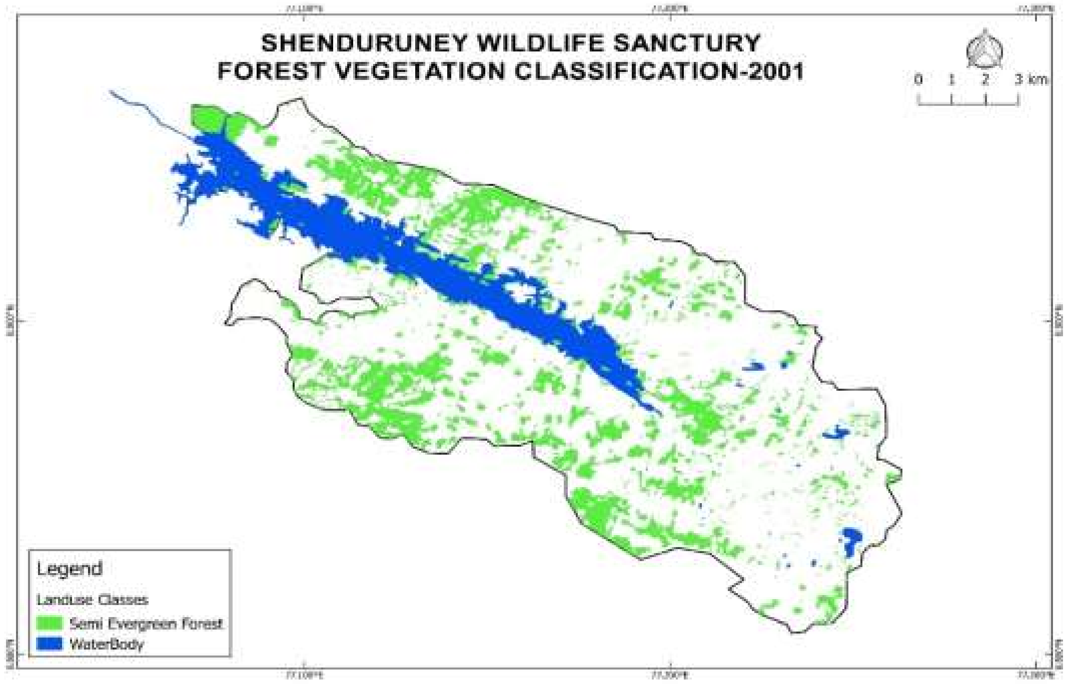


Figure 53. Spatial distribution of semi-evergreen forest vegetation classification 2001

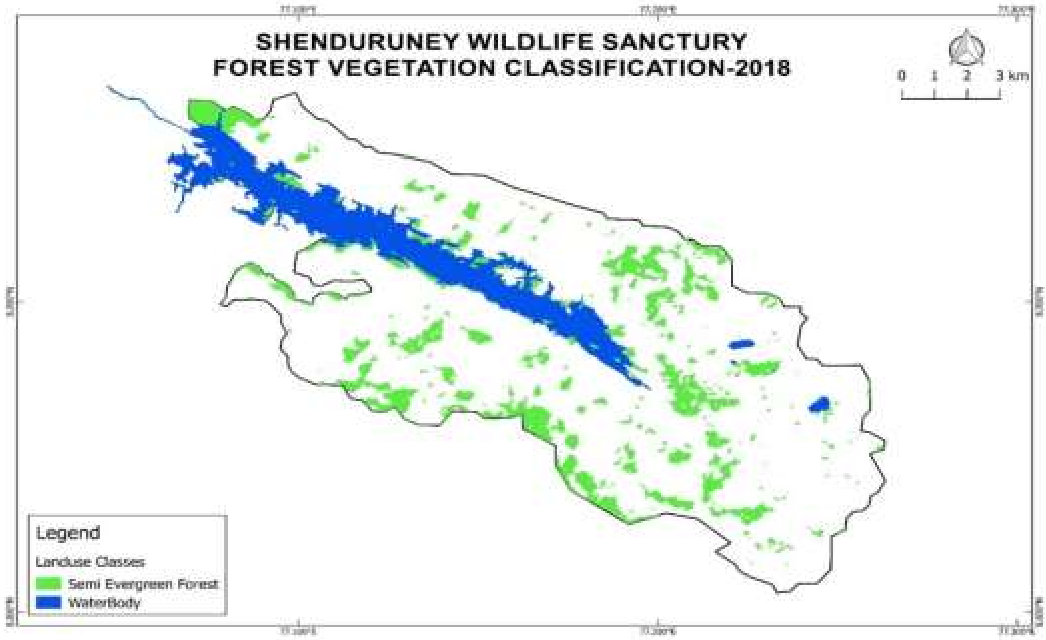


Figure 54. Spatial distribution of evergreen forest vegetation classification 2018

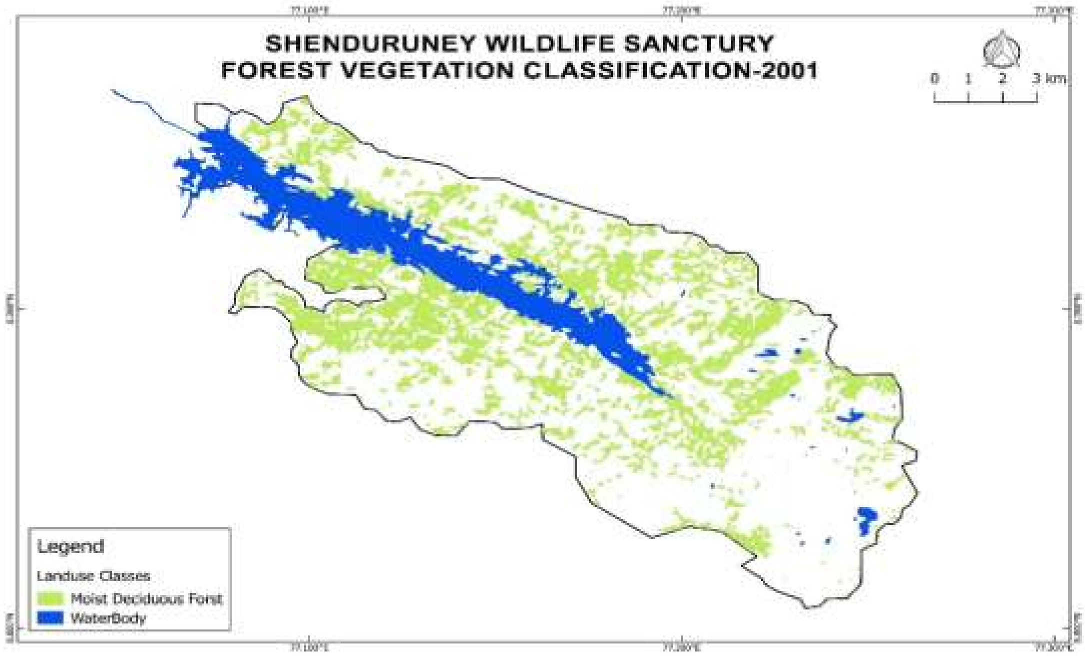


Figure 55. Spatial distribution of moist deciduous forest vegetation classification 2001

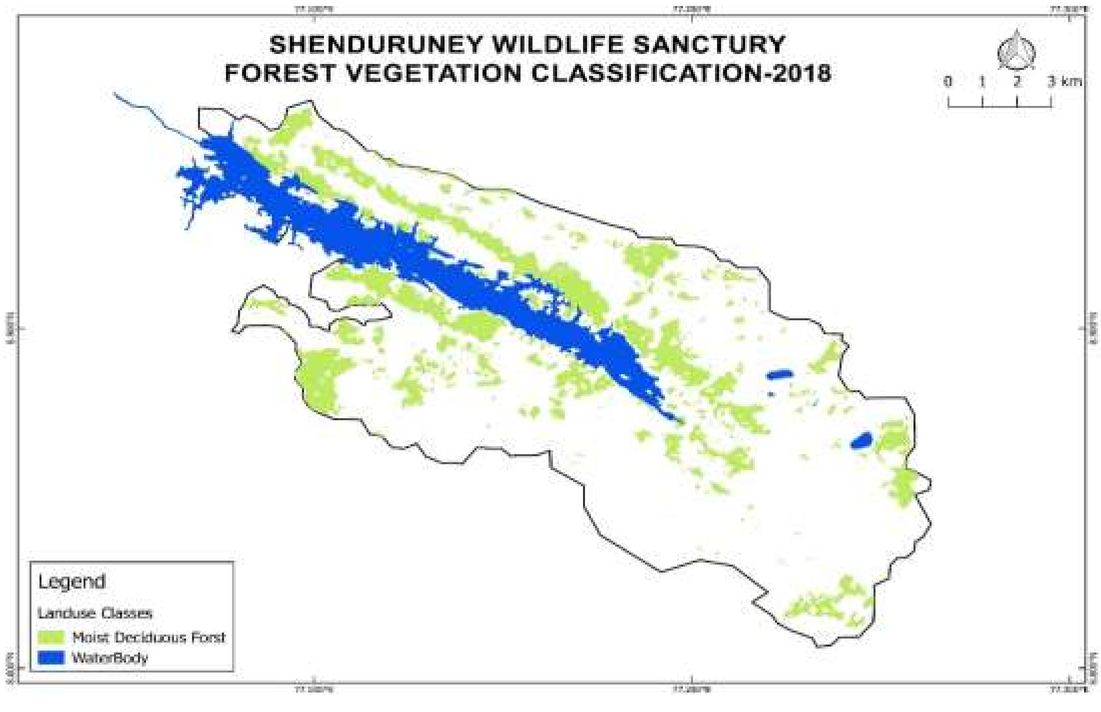


Figure 56. Spatial distribution of moist deciduous forest vegetation classification 2018

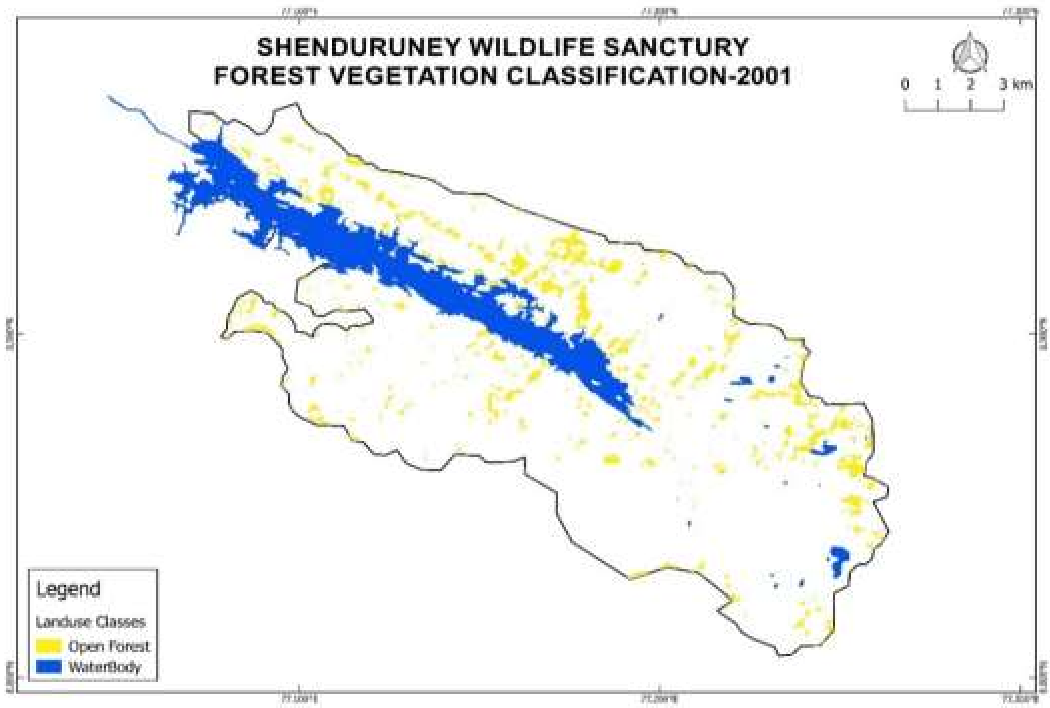


Figure 57. Spatial distribution of open forest vegetation classification 2001

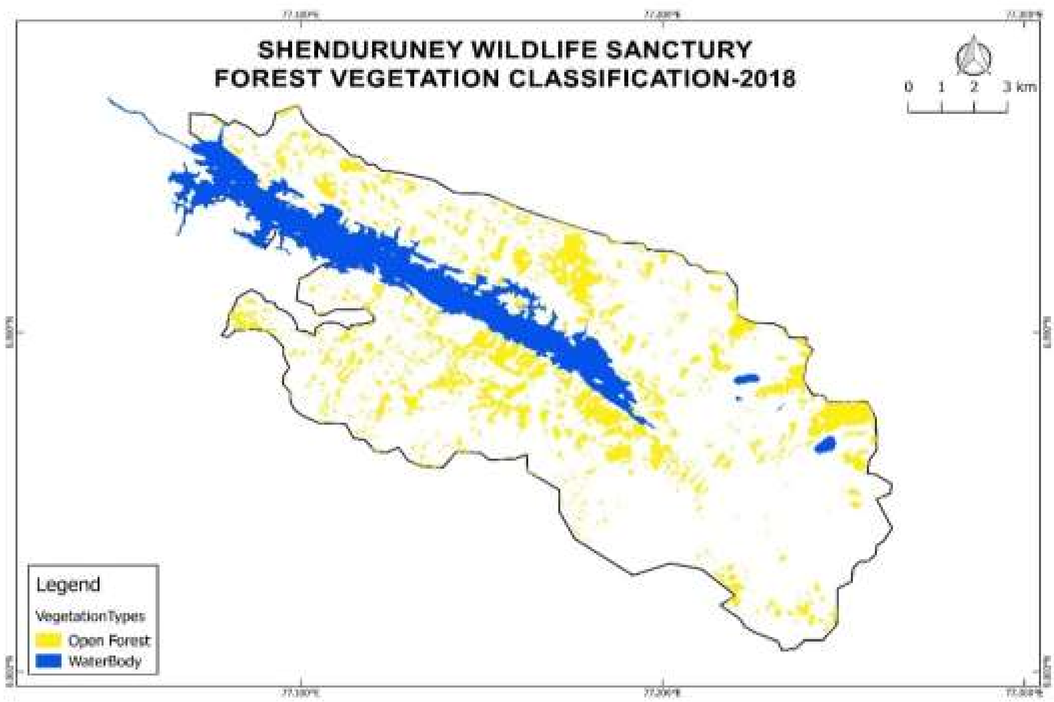


Figure 58. Spatial distribution of open forest vegetation classification 2018

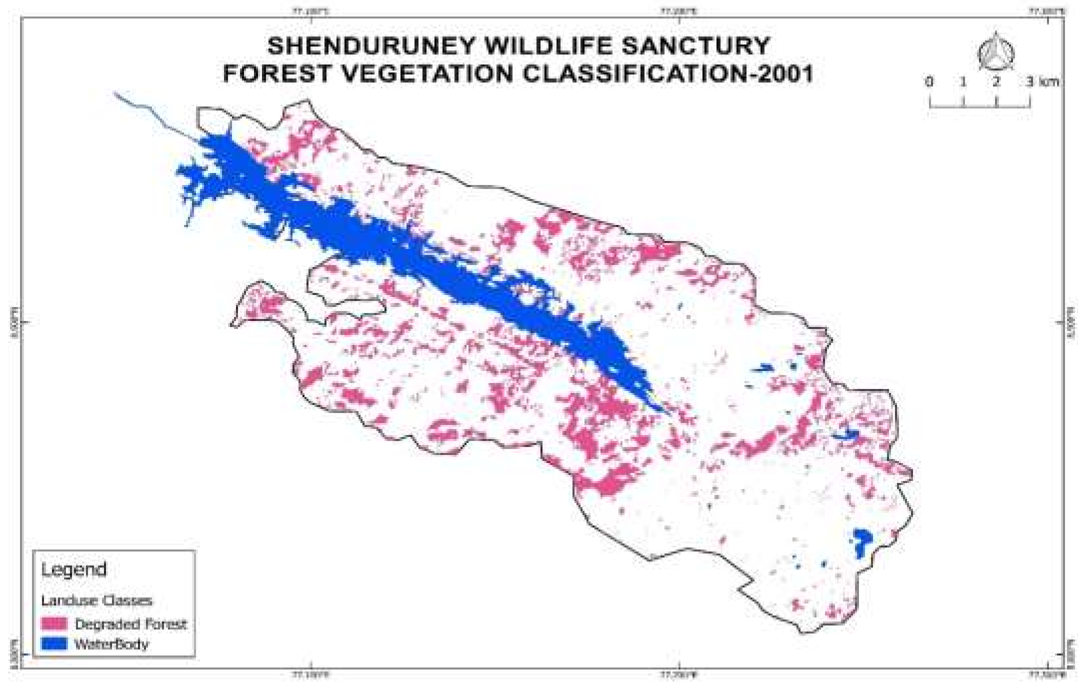


Figure 59. Spatial distribution of degraded forest vegetation classification 2001

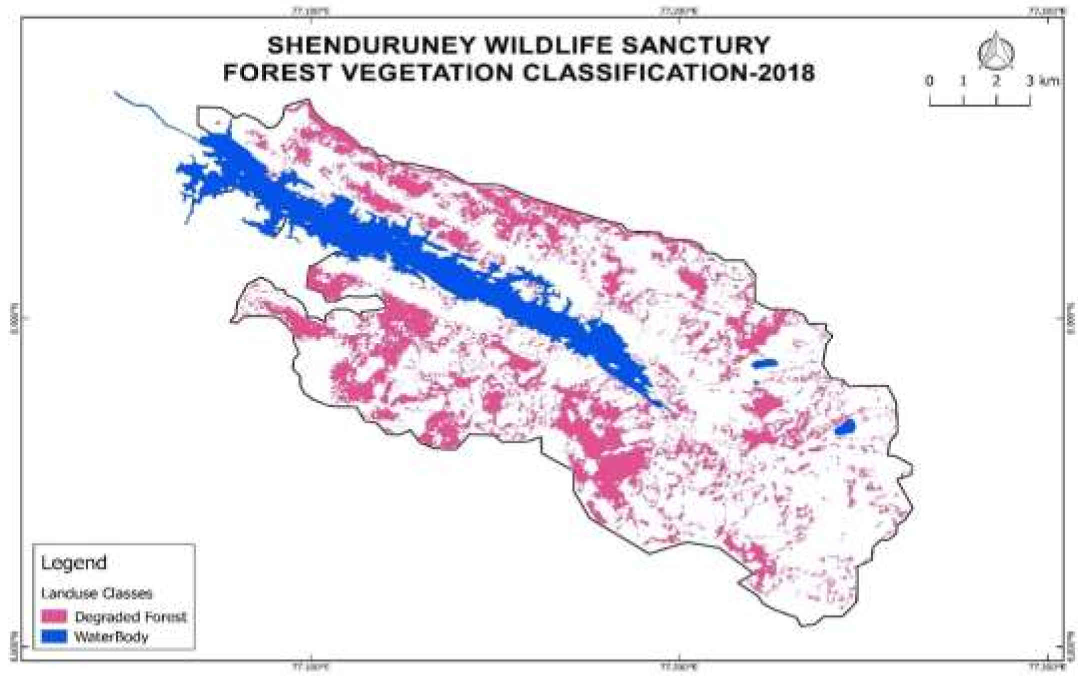


Figure 60. Spatial distribution of degraded forest vegetation classification 2018

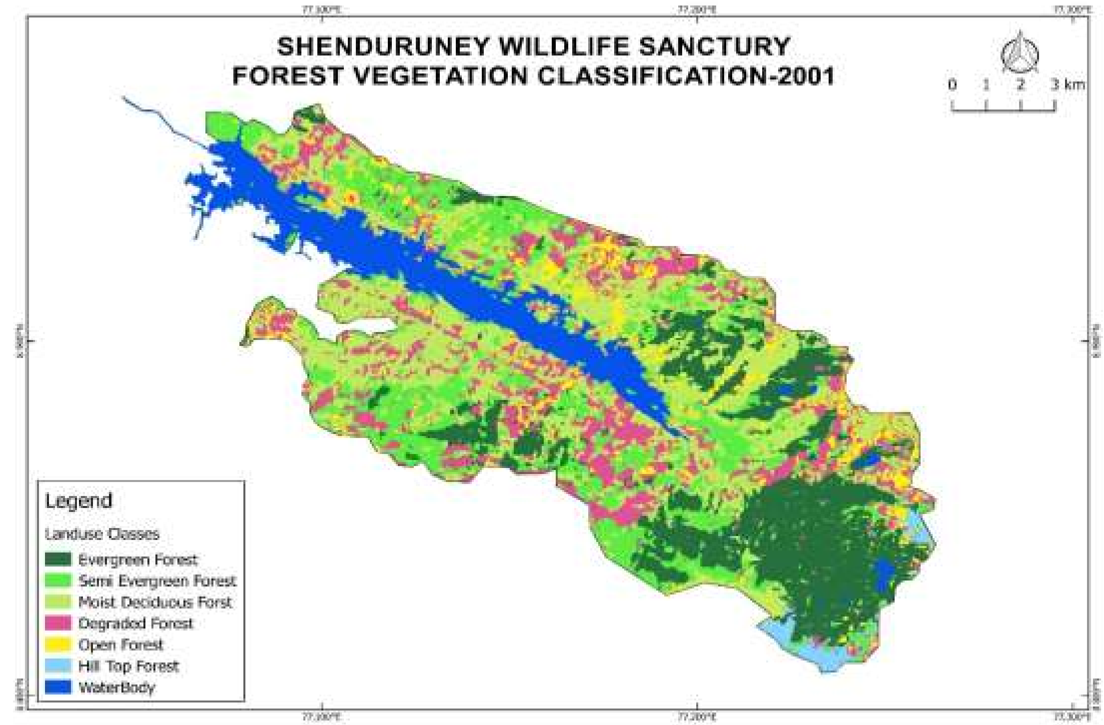


Figure 61. Spatial distribution of all the forests vegetation classification 2001

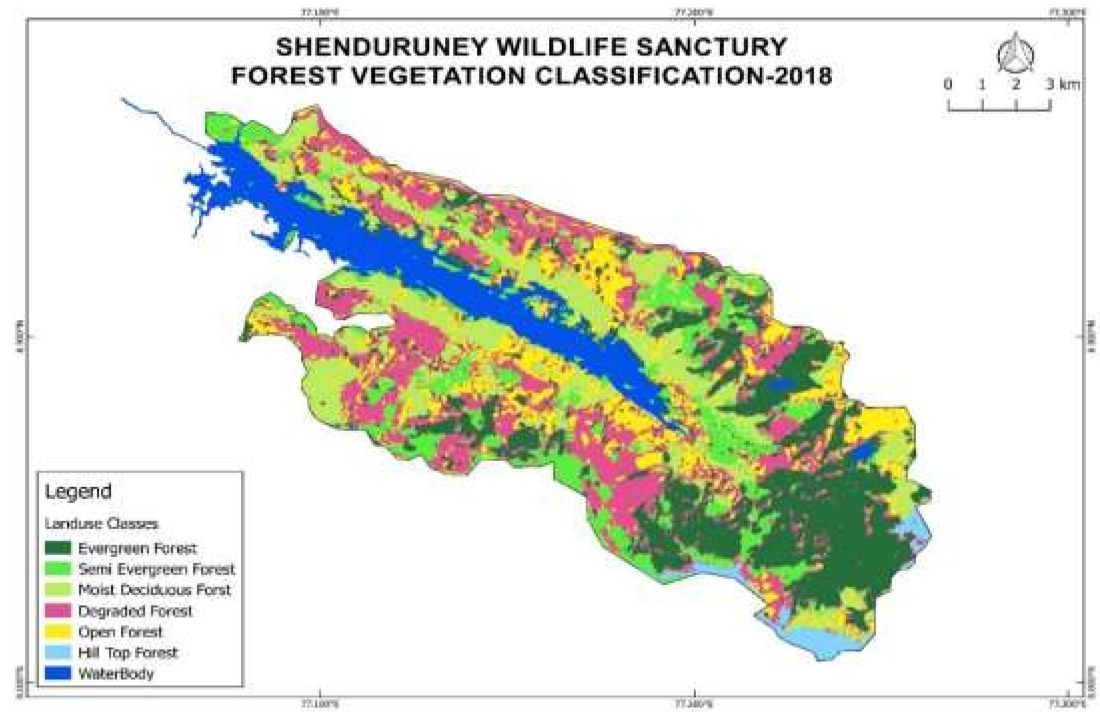


Figure 62. Spatial distribution of all the forests vegetation classification 2018

Discussion

DISCUSSION

This study, "**Phytosociological and edaphic attributes of forest ecosystems of Shendurney Wildlife Sanctuary, Kollam, Kerala**," was conducted from 2018 to 2020 in the Shendurney Wildlife Sanctuary, which is considered as one of the richest centers of floral diversity with a high degree of species endemism. Five major forest ecosystems, viz. West Coast Tropical Evergreen, West Coast Tropical Semi-evergreen, Southern Secondary Moist Deciduous, Myristica Swamp, and Tropical Hilltop forest were considered dominant forest types in this sanctuary. The comparison between the five forest types was evaluated. However, because the ecosystems are entirely different in structure, habitat, and composition, the literature that compared the ecological attributes of different forests similar to the present is difficult to get. Therefore, the ecosystems are compared with other work done on similar ecosystems, and the discussion based on that is presented here below:

5.1. Girth class distribution

The girth class distribution is an important attribute of the stand that gives a structural and graphical representation of the different girth classes (Kumar and Desai, 2016 a). The girth class distribution pattern of tree species revealed different patterns of population structure, suggesting that the species have different population dynamics. The diameter distribution represents the impact of disturbances within the forest (Denslow 1995). It can be used to spot trends in regeneration patterns (Poorter *et al*., 1996). The pattern of girth class distribution of the forest ecosystems of Shendurney wildlife sanctuary varies significantly across the forest types, with some forests manifesting reversed J-shaped distribution and typical L-shaped distribution. The pattern of girth class distribution for the evergreen and semi-evergreen forests was inverted J-shaped (fig. 2 and fig. 10), which is a general trend of the typical population structure. The majority of the species had the most significant number of individuals in the lower girth class, decreasing gradually as the girth class increased. The evergreen forest stocked more individuals of the large girth class categories, which is considered an indicator of undisturbed old-growth forest. A similar pattern of girth class distribution was also reported by Anbarashan and Parthasarathy (2013); Ramirez-Marcial *et al*. (2001).

The relatively high density of tree species in the lower girth classes (10-30, 31-60, 60-90, 91-120 cm) in some forest types and the predominance of tree species in higher girth classes, such as in the evergreen forest, manifested the health of the forest and free from disturbances, and the growing forest is efficiently utilizing the resources. The girth class distribution in the evergreen forest suggests that the forest is at the stage of regeneration. The forest ecosystem is potentially and efficiently utilizing resources.

The species richness and stem density of tree species decreased with an increase in girth class in moist deciduous forests. A similar trend was recently reported by Sahoo *et al*. (2020) in the moist deciduous forest of the Eastern Ghats of Odisha. The subsequent drop in stem density with increasing girth classes was reported by Ganesh *et al.* (1996) for the evergreen forest KMTR of the Western Ghats region. In the present studies, the decline in stem density in the lower girth classes is noticeable in the moist deciduous forest. This is in agreement with the investigation by Muthuramkumar *et al.* (2006).

The lack of individuals in the larger size classes in the moist deciduous forest could be attributed to the removal of giant trees for timber and construction purposes or that the forest has limited species that grow larger than these diameters (Hadi *et al*., 2009). While that of the hilltop forest could be due to the windy nature of the area. The lower density or number of individuals in the lower girth class (10-31 cm) compared to the girth class (31-60 cm) in the hilltop forest of the current investigation gives the appearance of a positively skewed distribution curve (fig. 34). The population structure of semi-evergreen and evergreen forests manifests a typical mature stand with adequate regeneration.

5.2 Altitudinal range of distribution

In the Western Ghats, the impact of altitudinal changes on species richness has not been well documented (Ganesh *et al.,* 1996). Unlike in wet evergreen forests with a broader range of altitudinal gradients up to 1800-2000 m in some forests of the Western Ghats region, the elevation of Shendurney Wildlife Sanctuary is rarely above 1300 m. The species richness in the wet evergreen forest of Shendurney Wildlife Sanctuary demonstrated an increasing trend with elevation. The changes are attributed to a change in vegetation types from the wet evergreen forest to hilltop tropical forest formation. A similar trend of vegetation changes was reported in the Kakachi forest of the Western Ghats (Ganesh *et al.,* 1996). Changes in species formation have been observed, with some showing a narrow range of distribution. The low elevation wet evergreen forest constituted the domination of species like *Baccaurea courtellansis, Psydrax dicoccos, Cinnomomum malabatrum, Diospyros candolleana, Anaclosa densiflora, Dipterocarpus bourdillonii,* and *Xanthophyllum arnottianum.* In the lower elevation evergreen forest, moist deciduous species like *Terminalia paniculata, Macaranga peltata,* and *Sapindus laurifolius* were reported, which is not surprising due to the transitional nature of the lower altitude evergreen forest as well as the high degree of degradation due to human settlements. The present study reported species like *Dipterocarpus bourdillonii*, *Lophopetalum wightianum,* and *Kingiodendron pinnatum* confined to the lower elevation (0-500 m). However, *Kingiodendron pinnatum* is rare and absent in some plots of the low elevation evergreen, and showed a peculiar distribution pattern, and has become more abundant in the semi-evergreen forest. Pascal *et al*. (2004) reported a similar pattern of species distribution and stated that these species are confined to an elevation ranging of between 0-800 m. The medium elevation is defined by the composition of species like *Dysoxylum malabaricum*, *Xanthophyllum arnottianum*, *Hopea parviflora,* and *Vateria indica*.

Contrary to the present study, the semi-evergreen forest species *Schleichera oleosa* has shown a wider ecological distribution to the medium elevation up to 730 m elevation and was found in association with species like *Xanthaphyllum arnottianum, Diospyros candolleana,* and *Dysoxylum malabaricum* (Honey, 2020). The species like *Mesua ferrea, Diospyros candolleana*, have shown a wider range of ecological amplitude from low-medium-higher elevation. *Xanthaphyllum arnottianum, Vateria indica,* and *Hopea parviflora* were dominant in the lower to medium elevation evergreen forest.

Species such as *Xanthophyllum arnottianum* have shown high ecological amplitude and were found to be one of the ecologically dominant species in the west coast tropical evergreen, semi-evergreen, and patches of moist deciduous and Myristica swamp forest. This indicated its potential for a wide range of growth and adaptability. Some species were observed to be confined to particular altitudinal ranges, mainly above 750m elevation, i.e., *Gluta travancorica, Cullenia exarillata,* and *Symplocos cochinchinensis*; these species showed altitudinal limitation, although they were found at medium elevations between 750-800 m elevation in association with *Mesua ferrea*, *Diospyros condolleana,* and *Xanthophyllum arnottianum.* The ecological limitations of this species could be attributed to its adaptability to limited climatic conditions and specific ecological niches. In the above 1150 m elevation, beyond the Pondimotta region, the composition of the species has entirely changed, with species rarely exceeding 20 m in height and stunted. The prevalence of wind may be the primary reason for the formation of this type of vegetation. Species like *Measa indica, Syzygium densiflorum*, *Bhesa indica*, *Elaecarpus munroonii*, *Ardisia rhomboidea*, *Cinnomomum* spp, and *Vernonia travancorica* e.t.c are found in this region.

The changes in species composition with altitudinal variation may be attributed to variations in temperature, relative humidity, evapotranspiration rate, radiation value, and wind speed (Nakashizuga, 1992). The present study observed an altitudinal limitation (above 1100 m) of species belonging to the Dipterocarpaceae family, mainly *Dipterocarpus indicus*, *Hopea parviflora,* and *Vateria indica*. This finding is supported by Proctor *et al*. (1988). They reported that although the conditions were favorable for their growth, Dipterocarpaceae could not be found at a site above 770m elevation. Contrary to Ganesh *et al*. (1996), *Xanthophyllum arnottianum* was common only above 1400 m elevation. The present study observed that *Xanthaphyllum arnottianum* was common at lower and medium elevations among the dominant species. This finding is supported by Sundrapandian and Swamy (2000).

The species' compositional changes characterize the medium to a higher elevation (800-1200 m) evergreen forest of Shendurney. Toward the higher elevation, the forest appeared to be stunted. The difference in species composition with the increase in elevation was noticed by forming a new set of species belonging to the families of Clusiaceae and Lauraceae. Honey (2020) reported an increase in species belonging to the family Lauraceae with an increase in elevation.

Despite the observed gradual transformation in the species composition with increasing altitude, this study also noticed the complete replacement of deciduous species like *Schleichera oleosa* in the medium elevation up to 600 m. A similar trend of species transformation was seen in the evergreen forest of Agumbe, a region of the Western Ghats. These changes could be attributed to changes in temperature and wind velocity. Srinivas and Parthasarathy (2000) reported high species richness (71) per hectare and observed a negative correlation between species richness and altitude in the Agambe rainforest of the central Western Ghats.

5.3. Phytosociology

The phytosociological study of different forest types in Shendurney Wildlife Sanctuary was carried out at the tree and regeneration level to achieve an almost complete species inventory. The understory vegetation defines the probable future of the forest under normal conditions (Sakar and Devi, 2014). The details obtained from this study generated an idea about the phytosociological attributes of the tree species at various levels or strata of all the five major forest types of the Sanctuary.

5.3.1. Species richness, community structure, and composition of forest types

The current inventory has recorded the richness of all the five forest types in the study area. The species richness was significantly higher in the evergreen, followed by the semi-evergreen forest, probably due to the high rainfall and optimal climatic conditions. The species richness was relatively lower in the hilltop forest and may be attributed to a lower temperature and wind velocity in the higher elevation. Jayakumar and Nair (2013) had a similar view on tree species richness. The moist deciduous forest is usually a low elevation forest proximate to human disturbances, directly impacting the species richness and increasing the dominance of a single or few species. According to Chaneton and Facelli (1991), disturbances increase dominance and decrease community spatial heterogeneity. The lower richness of tree species in the myristica swamp can be attributed to the habitat of accumulating species capable of thriving inundation throughout the year.

The tree species richness reported from the wet evergreen forest of the current work was comparably lower (119 species) than the 125 species reported by Sundarapandian and Swamy (2000) in the evergreen forest of Kodayar in the Western Ghats; and the 144 species (Parthasarathy, 1999) recorded in the southern Western Ghats. However, the value was higher than 118 species reported by Ramachandran and Swarupanandan (2013) from the Nellianphathy Southern Western Ghats; 90 species (Ganesh *et al*., 1996) from the Southern Western Ghats; 91 species (Pascal and Pelissier, 1996) central Western Ghats; 94 species (Nath *et al*., 2005) from northeast India and 54 species (Bhuyan *et al*., 2003) from the eastern Himalaya. Whitmore (1984), in the tropical rain forest reported that, the number of tree species counted per hectare varies between a minimum of 20 and a maximum of 223. In the present study, the species richness of the evergreen forest is comparatively modest. However, the comparisons between the present study and different other findings elsewhere could be an inadequate approach since a different methodology has been adopted, such as the size of the plots, which greatly affect the output of the study.

The species richness recorded in the tropical semi-evergreen forest in the present study was found to be 101. A similar finding was reported (100 species) in the Similipal Biosphere Reserve (Reddy *et al*., 2007), and a higher number of species than reported by several researchers in many of the tropical forests (Kadavul and Parthasarathy, 1999; Devi and Yadava, 2006). The significant variation in species richness between the present study and other studies elsewhere could be attributed to the sampling approach, elevation, DBH category, and edaphic attributes. In the present study, the sample plots were selected randomly across altitudinal gradients, unlike other studies where the sampling approach was mainly restricted to one location. Some studies established a permanent plot. The variation in species richness and composition could be largely due to elevation, bioclimatic and edaphic factors. Liebarman *et al*. (1996) have a similar view on species richness. The species richness recorded in the moist deciduous forest of the present study was 58, with the domination of *Terminalia paniculata* and *Aporosa cardiosperma* (Table 13). A similar number of species 58, and a species domination pattern was reported in the moist deciduous forest of the Kodayar Western Ghats (Sundarapandian and Swamy 2000). Naidu and Kumar (2016) recorded 129 species from the Eastern Ghats' tropical deciduous forest; 125 species were recorded in the tropical moist deciduous forest of Odisha (Reddy *et al*., 2007). Murthy *et al*. (2016) also observed a similar domination pattern of *Terminalia paniculata* and *Aporosa cardiosperma* in the moist deciduous forest of the Uttara Kannada Western Ghats. Kumar *et al*. (2010a), in their studies in the deciduous forest of western India, recorded 93 species. Comparatively, the species diversity reported in the moist deciduous of the current investigation is modest.

In the myristica swamp forest, thirty-three species were recorded which is lower than the sixty-three species reported in the swamp of Uttara Kannada (Bhat and Kaveriappa, 2009). In the current study, the species richness observed for the myristica swamp forest is comparably lower than in the other studies. This may be attributed to the size of the myristica swamp and the small sampling size employed. The species richness in the hilltop forest of the current study is higher than in the hilltop forest reported by Khera *et al*. (2001). The most noticeable variation in tree species and the emergence of dominant species in forest types can be traced directly to altitudinal and rainfall differences.

5.3.2 Species diversity and community structure

The diversity assessment of species is an important attribute in ecological studies that gives details about richness and evenness. According to Pianka (1966), species diversity is caused due to different interactions like competition among the existing species and variation in ecological niches, which are demonstrated in the tropical region due to the relatively high humidity and temperature (Ojo and Ola-Adams, 1996). The diversity of species is considered an essential parameter for evaluating an ecosystem. In a rich ecosystem with high species diversity, H' has a large value, contrary to low species diversity ecosystems (Deka *et al.,* 2012). Species diversity indices indicate the relative importance of factors that influence the population entirely (Rao *et al*., 2014). The value of diversity indices of different forest ecosystems in the present study varied significantly, with relatively higher to medium across the ecosystems.

The diversity of tropical forests is astounding (Paijams, 1970), and different factors influence their diversity (Connell 1971; Hubbell 1979). The Western Ghats region is considered one of the world's richest biodiversity, harboring over 3500 flowering plants from the 17000 species accounted in India (Myers *et al*., 2000). High species richness is one unique attribute associated with the tropical forest. Diversity is usually correlated with precipitation, nutrient availability (Hartshorn, 1980), and disturbance gradient (Rao *et al*., 1990). The number of species recorded varied significantly across the forest ecosystems of this study, with the highest species richness observed for the tropical wet evergreen forest.

The Shannon index H’ is generally higher in tropical forests, and species diversity is dependent on species adaptation and increases with community stability (Knight, 1975). The Shannon index of diversity for Indian forests ranges from 0.83 to 4.10 (Singh *et al*., 1984). Across all the forest ecosystems of the present work, the Shannon index ranged from (2.70-4.10), which falls within the range of 0.83 to 4.10 reported for the Indian subcontinent (Ayyapan and Parthasarathy, 1999; Panda *et al*., 2013). The highest value 4.10, was recorded for tropical evergreen and semi-evergreen forests. The higher value reported for the semi-evergreen forest similar to evergreen could be attributed to the larger sampling area. Scheiner (2003) emphasized that an increase in sample area increases species richness because new individuals are comprised, and large areas are more heterogeneous than small areas. The possible reason for the relatively higher species diversity of the evergreen forest of Shendurney could be due to the altitudinal wise sampling approach adopted, which has shown increasing species richness with elevation change.

The Shannon index of diversity value for the evergreen forest of Shendurney appears to have a higher value than other sites in the Western Ghats region, such as Silent Valley (Basha *et al.,* 1992), Attapady (Pascal, 1988), but lower than that of the Kalakad-Mundanthurai tiger reserve of the Western Ghats (Giriraj *et al.,* 2008), and for the Kakachi forest of Agasthyamalai (Ganesh *et al.,* 1996). The current value seems to be in the medium range and within the range of 3.6 to 4.3 for the Western Ghats' climax, evergreen forest reported (Varghese and Balasubramanyan, 1999). The differences in the area sampled, the lack of uniform plot dimension, and standard girth classes make the comparison difficult between the sites (Magurran, 1988).

Because of their species diversity, tropical semi-evergreen is considered the most important ecosystem on the planet (Givnish, 1999). This particular study recorded a higher value of 4.09 in the tropical semi-evergreen forest (Table 31), comparatively higher than the (2.66-3.07) reported by Kadavul and Parthasarathy (1999) in the semi-evergreen forest of the Eastern Ghats but lower than the 5.46 recorded (Reddy *et al.,* 2007) in the tropical semi-evergreen of Odisha. The value recorded in the present investigation is, therefore, in a modest range. In the tropical moist deciduous forest, the Shannon index reported for the present study was 3.22 (table 36), higher than the range reported (Panda *et al*., 2013) in the tropical moist deciduous forest of the Eastern Ghats; Murthy *et al.* (2016) in the moist deciduous forests of the Western Ghats; and recently (Ramya *et al*., 2020) in the Karamadai reserve forest of the Western Ghats. However, the value was within the range reported (Sahoo *et al*., 2017; Sahoo *et al.,* 2020) but lower than reported by Reddy *et al*. (2007) and Reddy *et al*. (2008).

The myristica swamp forest showed the lowest 2.70 value of the Shannon index among the forest ecosystems studied in Shendurney (Table 31). However, the value is higher than reported swamp forests elsewhere (Varghese and Kumar 1997; Varghese and Menon, 1999) but lower than what is reported by Varghese and Kumar (1997); Sreejith *et al*. (2016). The relatively lower Shannon H' diversity in the Myristica swamp could be due to the domination of a few species, accounting for more than 34% of the relative density. Only three species constituted 53 percent of the total number of individuals.

Bijalwan *et al*. (2009) have a similar view on species diversity in their study of dry tropical forests. The diversity is attributed to the number of species, and that the forest ecosystem with a higher number of species is expected to have higher value diversity. However, some of the diversity indices like Shannon and Weaner are influenced by dominance and rarity (Abhilash and Menon, 2009). In the current study, the similarity in the value of the Shannon index between the tropical wet evergreen forest and the tropical semi-evergreen forest could be due to the lack of absolute dominance in the semi-evergreen forest and the pattern of species distribution with variation in dominant species across the forest strata and contiguity of the ecosystem patches. Comparison is difficult due to the lack of consistent plot dimensions, standard diameter classes, and variations in the sampled area (Sundrapandian and Swamy, 1998).

The Simpson index was calculated in the current study. The values have shown significant differences across the forest types, with the highest value of 0.97 recorded for evergreen and semi-evergreen forests. The higher value in evergreen and semi-evergreen could be due to the high relative abundance of the species and lack of absolute dominance of few or single species. The lowest value in the myristica swamp is due to the dominance of a few species of the Myristicaceae family; the lowest value, 0.92, was followed by the tropical moist deciduous, which has also shown the dominance of a few species. The Simpson index value of 0.97 for the evergreen forest in the current work was higher than 0.95 for the wet evergreen of Kakachi KMTR (Giriraj *et al*., 2008). The Simpson recorded in the present study for semi-evergreen was comparatively similar to 0.96 reported by Reddy *et al*. (2007).

The present investigation recorded the Simpson index value as 0.92 for the moist deciduous forest, which was higher than 0.85 and 0.90 for less disturbed forest sites and 0.82 and 0.91 for more disturbed sites. However, lower than 0.94 of less disturbed and similar to 0.92 of more disturbed moist deciduous forests of Uttara Kannada of Western Ghats (Murthy *et al.,* 2016), 0.96-0.97 (Naidu and Kumar, 2015); 0.94 (Reddy *et al*., 2008). For the swamp of Shendurney, the Simpson index of diversity found is 0.88 higher than for Kulathupuzha 0.73 (Varghese and Kumar, 1997); 0.83 (Varghese and Kumar, 1997) but lower than the

0.93 reported by Bhat and Kaveriappa (2009) in Uttara Kannada. The Simpson index of the myristica swamp is in the medium range.

Bijalwan *et al.* (2009) reported that the Shannon and Simpson index of dry tropical forest ranged from 2.14 to 2.86 and 0.07 to 0.14 in the overstorey and varied from 2.01 to 2.88 and 0.09 to 0.58 in the understorey. This value was comparatively lower than the 3.4 to 4.8 reported by (Singh *et al*., 1984) and other studies in India's tropical forest. The Shannon and Simpson index showed an inverse relationship in some forest types of the current investigation. Murthy *et al*. (2016) observed a similar pattern of association. The result showed that semi-evergreen and evergreen forests are floristically rich in diversity and complexity. The value of the Simpson index in the present study across the forest types is comparably in the medium range.

The Simpson index of dominance varies significantly across the forest ecosystems of the study area. Across the forest ecosystems, the value of dominance was recorded higher in myristica swamp forest and lowest for tropical semi-evergreen forest and tropical evergreen forest. The higher value of the concentration of dominance indicates the dominance of a single or few species. Giliba *et al*. (2011) reported that the higher the index value, the higher the species dominance and vice versa, and that the greater the value, the lower the species diversity (Misra, 1968). This is consistent with the present study in most of the forest ecosystems. The higher value obtained in the myristica swamp forest is attributed to the single species dominance of *Myristica fatua* and *Myristica dactyloides.* In contrast, the lowest value observed in the tropical evergreen and semi-evergreen forests could be due to the lack of absolute dominance.

The concentration of dominance for the wet evergreen forest of the current study was recorded at (0.028), which was less than the (0.089) reported by Chandrashekara and Ramakrishnan (1994); 0.125-0.157 (Sundarapanian and Swamy, 2010). The lower value of the concentration of dominance in the tropical evergreen forest in the present study revealed that the tropical evergreen forest is a mixed type of humid tropical forest. The concentration of dominance is higher where species are dominated by a single or few species. The value of 0.078 of concentration of dominance for moist deciduous is comparatively lower than the recently reported 0.135 (Ramya *et al*., 2020). The Simpson index weights heavily towards the abundant species in the sample and is less sensitive to species with only a few individuals (Magurran 1998; Pandey and Shukla 2003). A low Simpson index reflected that disturbances resulted in low equitability and high dominance because of the congruent exploitation of the species.

The variation in the composition and proportion of tree species across the forest ecosystems could be attributed to variations in microclimate and topography. The moist deciduous forest was among the forest ecosystems that showed a high degree of species dominance and those that reflected the impact of disturbance and significant loss in its extent. According to Keel and Prance (1979), dominance increases due to stress. The higher dominance in the myristica swamp forests could be due to the domination of a few species capable of thriving inundation throughout the year.

The equitability or evenness index indicated the extent of representation by an equal number of individuals in the studied plot. The higher the value, the greater the equality of the species. Among the forest ecosystems of the present study, the value of the equitability (J) index ranged from 0.76 to 0.90, with the highest value observed for tropical hilltop forest and the lowest for myristica swamp forest. The highest value in the hilltop forest could be due to the high species evenness. The lowest value for the myristica swamp could be due to the dominance of a few species. In a tropical forest, equitability signifies the high evenness of individuals distributed among the sampled species (Sarkar, 2016). The value of 0.79 of the equitability index recorded for the tropical moist deciduous in the present is comparatively lower than the recently reported 0.94 (Ramya *et al*., 2020).

The species evenness is defined as the extent to which individual species are divided between the species, with a low value indicating one or few species dominance, while a high value manifests a moderately equal number of individuals are fairly represented (Morris *et al*., 2014). The present work recorded a 0.70 higher value of species evenness for tropical hilltop forest followed by 0.59 for tropical semi-evergreen forest and the lowest (0.43) for moist deciduous forest and 0.43 for myristica swamp forest, indicating relatively higher dominance of one or a few species in moist deciduous and myristica swamp forests compared to tropical hilltop forest and semi-evergreen forest. The higher value of evenness manifested more consistency in the species' pattern of distribution.

In the evergreen forest of the current investigation, the value of 0.49 of species evenness is comparably lower than the 0.89 reported in the evergreen forest of the Agasthyamalai region of the Western Ghats, Sundrapandian and Swamy (2000) reported a higher value of 1.69 in the evergreen forest of Kodayar. In the wet evergreen forest, Giriraj *et al*. (2008) reported a relatively similar value of 0.79 for the Kakachi range of Agasthyamalai. The evenness recorded as 0.59 was comparably lower than 0.83 (Sarkar and Devi, 2014) in tropical semi-evergreen of HGWLS.

Ramya *et al*. (2020) recently reported higher evenness in the moist deciduous forest of the Veerakkal area of Nilgiris, than in the current study. However, the values reported in the deciduous forest in the present study were comparably higher than the range reported by Murthy *et al*. (2016) in the moist deciduous forest of Uttara Kannada. However, it is comparatively lower than the range reported by Naidu and Kumar (2015) in the tropical deciduous forest of Andhra Pradesh; Sahoo *et al.* (2017) in the tropical moist deciduous forest of Nayagarth forest division of Odisha; and Sahoo *et al.* (2020) for the tropical moist deciduous forest of the Eastern Ghats, Odisha. Therefore, the evenness value of the present study is within the range of values reported by several authors elsewhere.

The Margalef index is a vital diversity index that measures species richness, and it is notably sensitive to sampling size (Maguran, 2004). Across the forest types of the current investigation, the higher value of Margalef was observed for the tropical evergreen forest (15.42) compared to the tropical semi-evergreen forest (13.15), moist deciduous forest (7.90), hilltop forest (7.05), and myristica swamp forest (5.58). Despite the larger sampling area of semi-evergreen forests, the

Margalef showed higher value in the evergreen forest. The higher value observed in this study could be due to the species richness, not the sampling area. It may be suggested that species richness influences the Margalef value. The Margalef index value of 7.07, recorded in the evergreen forest of the Agasthyamalai region by Varghese and Balasubramanyan (1999), was significantly lower than that of the evergreen forest of the current inventory. In the moist deciduous forest of the present study, the Margalef value recorded was (7.90) lower than the range reported by Kumar *et al.* (2010) in the deciduous forest of the Western Ghats, but higher than recently reported by Ramya *et al.* (2020) in the moist deciduous forest of Karamadai of Western Ghats region. Moreover, the value is within the range reported in the moist deciduous and dry deciduous forests of Mudhumalai (Reddy *et al.,* 2008). However, these values are comparatively higher than the 18.5 recorded from the humid subtropical forest of Meghalaya (Misra *et al*., 2005). Across all the forest ecosystems of Shendurney, the Margalef value was comparatively modest.

5.3.3. Structural dynamic in forest ecosystems

The species composition and dominance of the tropical evergreen forest of Shendurney showed the pattern of *Xanthophyllum arnottianum, Mesua ferrea,* and *Cullenia exarillata* as the dominant species. Therefore, they were considered as *Cullenia-Mesua-Xanthophyllum,* which fits the classical *Cullenia-Mesua-Palaquium* series of the medium elevation (700-1400 m) described in the wet evergreen forest (Pascal, 2004). Similar vegetation classification was reported in many of the wet evergreen forests of the Southern Western Ghats, like that of Attapadi mid-elevation reserve forest with the dominance of *Cullenia-Mesua-Palaquium* (Pascal 1988), Kalakad national park with the dominance of *Cullenia-Aglaia-Palaquium* (Parthasarathy, 1999), and Kakachi mid-elevation forest of Agasthyamallai with the dominance of *Cullenia-Aglaia-Palaquium* (Ganesh *et al.,* 1996). The dominance of *Mesua ferrea* in the present study is more of relative density, relative frequency, and basal area. Unlike the co-dominant *Xanthophyllum arnottianum,* which has manifested the highest relative density of all the species but a lower relative basal area than the dominant species, *Mesua ferrea*. The species *Mesua ferrea* and *Xanthophyllum arnottianum* have shown higher ecological amplitude among the dominant tree species in the present study. *Cullenia exarillata* has shown narrow ecological amplitude, i.e., limited distribution to the medium 750 m elevation to higher elevations.

A study conducted by Parthasarathy (2001) reported that in the undisturbed medium elevation evergreen of Segaltheri, part of Agasthyamalai, the predominant species are *Toona ciliata* and *Litsea stocksii,* which are absent in the current inventory. Similarly, in Kalakad national Park, the domination of *Cryptocarya bourdillonii*, *Myristica dactyloides*, *Harpullia arborea*, *Palaquium ellipticum*, *Cullenia exarillata,* and *Mangifera indica* was reported (Parthasarathy, 1999). Sundrapandian and Swamy (2000), in their study along the altitudinal gradient (250-1100), reported a community structure composed of *Hopea parviflora*, *Vateria indica,* and *Xanthophyllum arnottianum*. This type of community structure is more represented by the Dipterocarpaceae family. Many studies, including the present, have reported the altitudinal limitation of species belonging to this family. Similar to the current investigation, in the Agasthyamalai region of the Western Ghats, Varghese and Balasubramanyan (1999) reported the wider ecological amplitude of *Mesua ferrea* and the tree community structure of the domination of *Mesua ferrea, Diospyros candolleana, Carallia brachiata,* and *Xanthophyllum arnottianum*. Out of the ten most dominant species in the evergreen forest of the present study, five species comprised of *Xanthophyllum arnottianum*, *Cullenia exarillata*, *Vateria indica,* and *Baccaurea courtellansis* are endemic to the Western Ghats region, and four species comprised of *Dysoxylum malabaricum*, *Diospyros candolleana*, *Gluta travancorica,* and *Kingiodendron pinnatum* are endemic to Southern Western Ghats respectively. However, two species are vulnerable to extinction in the future; one species is near threatened, and another is endangered. Abhirami (2020) reported zero endemism among the dominant species in one site of her ecological studies.

The current tree community structure reported in the semi-evergreen forest showed the pattern of *Baccaurea courtallensis*, *Hopea parviflora,* and *Xanthophyllum arnottinum.* The semi-evergreen forest, similar to the evergreen forest, has shown a composition shift across altitudinal gradients. The semi-evergreen of the current study was found across a specific range of altitudes, from lower to medium elevation. Although many species have shown their wider ecological amplitude, some species have been observed consistent with particular elevational gradients: lower-medium, medium-higher, and some species across all the elevations (lower-medium-higher elevation). In the lower elevation semi-evergreen forest, the following species are found only at lower elevations. *Macaranga indica*, *Dillenia pentagyna*, *Hopea ponga, Cassia fistula, Terminalia paniculata*, *Lagerstroemia microcarpa, Lagerstroemia speciosa, Grewia tiliifolia,* and the presence of *Macaranga indica* in the lower elevations may be associated with disturbance and forest degradation in the lower elevations. While species like *Holigarna arnottiana*, *Hydnocarpus pantendrus*, *Polyalthia fragrans,* and *Stereospernum colais*, *Flacourtia montana*, *Haldina cordifolia*, *Memecylum umbellatum*, *Melicope lunu-ankeda*, and *Melia dubia, Poeciloneuron indicum,* among others, are more confined to medium elevation. In the lower to medium elevation, species like *Mesua ferrea* are prevalent in the medium to higher elevation, while *Vitex altissima* is found in the lower lower to medium elevation. Across the elevational gradient, the following species, *Baccaurea courtallenis, Hopea parviflora, Xanthophyllum arnttianum, Diospyros foliosa, Cinnomomum malabatrum, Dysoxylum malabaricum, Pydrax dicocoss, Macaranga peltata, Vateria india* and *Pajanelia longifolia* have shown wider ecological amplitude and dominated in the semi-evergreen forest of the current study.

The community structure of the moist deciduous forest in the current study is characterized by the domination of species such as *Terminalia paniculata*, *Aporosa cardiosperma, Olea dioca*, *Bombax ceiba,* and *Tabernamontana alternifolia*. Similar species composition and domination patterns of *Terminalia paniculata*, *Aporosa cardiosperma,* and *Pterocarpus marsupium* were reported in the moist deciduous forests of the Kodayar region of the Western Ghats (Sundrapandian and Swamy, 2000).

In the current study, the tree community structure of the myristica swamp forest portrayed the community's representation by species belonging to the Myristicaceae family, mainly: *Myristica dactyloides*, *Myristica fatua,* and *Knema* *attenuata.* As obviously reported in many studies in the myristica swamp forests, the dominant tree community structures belong to Myristicaceae. Bhat and Kaveriappa (2009) reported the structure of the myristica swamp of Uttara Kannada that the community composed of Myristicacee families mainly: *Gymnacranthera farquhariana* as the dominant species and *Myristica fatua* as the co-dominant species. Similarly, the community structure of the myristica swamp of Kulathuphuzha in the Southern Western Ghats was defined by the representation of the composition of *Gymnacranthera farquhariana* and *Myristica fatua* as the dominant species (Roby *et al*., 2018). Many studies have reported that *Myristica fatua* is an important tree species in the swamps of the Western Ghats region. However, species like *Vateria indica*, *Hopea parviflora, Lophopetalum wightianum, Baccaurea courtellansis, Holigarna arnottiana, Cinnomomum malabatrum,* and *Xanthophylum arnottianum* were reported in an important association with myristica species in the current study. A similar association was also reported in many studies in the myristica swamp forest by Bhat and Kaveriappa (2009); Roby *et al*. (2018).

The species-wise analysis showed *Xanthophyllum arnottianum* was almost across all the altitudes and was found in almost all the forest types of the Shendurney wildlife sanctuary. This indicates a wide range of growth and adaptability of *Xanthophyllum arnottianum* throughout the sanctuary. This species can be classified as a "companion species" since it can live in any community without displaying any preference for it. This species most likely has a high ecological amplitude (Reddy *et al.,* 2008).

5.3.4. Importance value index

The importance value index (IVI) measures the species' ecological amplitude, which indicates the species' ability to establish itself in a wide range of habitats (Ludwig and Reynolds, 1988). The IVI is paramount to understanding the forest community and species' competitive potential in a forest ecosystem. In ecological research, the importance value index (IVI) generally manifests species' ecological importance in a particular ecological unit or ecosystem (Saho *et al.,* 2020). The lower importance value index of species indicates species that need particular conservation concern (Zegeye *et al*., 2006). In the tropical evergreen forest, the high IVI=12.25 exhibited by *Mesua ferrea* is mainly due to its high relative density, frequency, and dominance compared to other species. The co-dominant *Xanthaphyllum arnottianum* showed a high importance value index of (IVI=10.39) due to its high relative density and frequency. The IVI of the second co-dominant *Cullenia exarillata* (IVI=10.39) is attributed mainly to its relative density and basal area (Table 1). This value is comparatively similar to IVI=13.3 for the most dominant and IVI=11.5 for the co-dominant species reported by Kacholi (2014), but lower than (IVI= 20.06) reported by Ndah *et al*. (2013); (IVI= 39.60) reported by Ganesh *et al.* (1996) and (IVI=37.00) reported by Giriraj *et al*. (2008).

The IVI of the most dominant and co-dominant species (IVI=10.78 and 10.03) in the tropical semi-evergreen forest is relatively lower than reported (Kadavul and Parthasarathy, 1999; Devi and Yadava, 2006; Dash *et al*., 2020). In the southern moist deciduous forest, the IVI of the most dominant and co-dominant species, *Terminalia paniculata* and *Aporosa cardiosperma* (IVI=26.67), is relatively similar to (IVI=34.59 and 30.67) for the dominant and co-dominant species in the moist deciduous forest of the Nilgiris Western Ghats (Ramya *et al*., 2020). The higher ecological dominance of *Terminalia paniculata,* represented by IVI in the moist deciduous forest of the present study, is primarily due to its high relative density, frequency, and dominance compared to other species. The co-dominance of *Aporosa cardiosperma,* the high IVI, is mainly due to its high relative density and frequency.

In the myristica swamp forest, the importance value index (IVI) of the most dominant and co-dominant tree species (IVI=63.78 and 38.85) is comparatively higher than IVI=57.83 and 38.49 for the dominant and co-dominant species reported by Bhat and Kaveeriappa (2009) and similar to Roby *et al*., (2018). The Myristica swamp forest exhibited the dominance of *Myristica dactyloides* mainly due to the species' relative density, frequency, and dominance. The co-dominance species *Myristica fatua* showed high IVI due to its high value of relative density and frequency, for *Knema attenuata,* the high IVI is largely due to its relative frequency and dominance. The comparatively lower importance value index reported in the current, especially for evergreen, and semi-evergreen forests is due to the lack of absolute dominance due to stratified random sampling methods adopted, while the comparatively higher value of IVI in myristica swamp forest is due to the smaller size of the sampling area and dominance of one or two species.

The high IVI displayed by *Vernonia travancorica* in the tropical hilltop forest is attributed mainly to its high relative density and frequency. The high IVI co-dominant *Symplocos cochinchinensis* of IVI was more or less due to the relative density and frequency of the species. The manifestation of many species with a low value of IVI has signified the existence of rare species. The large number of rare species encountered in this study confirmed the consistently dependable opinion that most species are rare in the ecological community rather than common (Magurran, 2005). The low ecological status of most of the tree species reported in the present investigation, as demonstrated by the IVIs, can be attributed to a lack of dominance by any of these species, implying positive interaction between the species (Misra *et al*., 2012). However, the species rarity could be attributed to various factors, such as; poor species' seeds dispersal ability, natural and or anthropogenic disturbance, competition within the forest community, and high density-dependent (Schwarz *et al*., 2003; Comita *et al*., 2007).

According to Kadavul and Parthasarathy (1999), their study in Peninsular India concluded that the importance value index of the dominant species is higher in the disturbed than in the undisturbed forest. The present research backs up this hypothesis. Where disturbances exist, such as in the moist deciduous and Myristica swamp forests, the IVI of the dominant species is more pronounced than in relatively less disturbed forests. Keel and Prance (1979) emphasized that dominance increases as a function of stress. In the present study, the proportion of dominant species differs among the forest sites because of differences in site characteristics such as site history and human impacts. The lack of dominance by any of the tree species in some forest types of the current investigation, as shown by the IVIs, could be due to their low ecological status, implying positive interaction among the tree species (Misra *et al*., 2012).

5.3.5. Family importance index

The present study observed a maximum family important index for Dipterocarpaceae and Clusiaceae in the tropical evergreen forests. The high FIV of the dominant family Dipterocarpaceae in the evergreen forest is mainly due to the high species richness of the constituent species. Several studies have reported the domination of the family Dipterocarpaceae in the wet evergreen forest; Bhuyan *et al*. (2003) in the evergreen forest of the Eastern Himalaya, Sundarapandian and Swamy (2000) in the Kodayar evergreen forest of the Western Ghats.

The current study observed the familial importance of Dipterocarpaceae and Clusiaceae in the tropical evergreen forest. Hooker (1906) reported that the most distinguishing attribute of the 'Malabar' flora compared to the Deccan is the presence of the Clusiaceae, Dipterocarpaceae, Myristicaceae, Bambusaceae, and Arecaceae. Pascal (1988), in his study, reported that the Euphorbiaceae and Anacadiaceae are the most important represented families in the Uppangala forest of the Western Ghats region. In Tamil Nadu's part of Agasthymalai, Ganesh *et al*. (1996) observed that the most represented families are the Lauraceae, Rubiaceae, and Euphorbiaceae. Varghese and Balasubramanyan (1999) reported the high familial representation of Clusiaceae, Myrtaceae, and Lauraceae. They emphasized that the family Euphorbiaceae was dominant in terms of species richness. Srinivas and Parthasarathy (2000), in their study of the Agambe rainforest of the Western Ghats, observed that the dominant families are Clusiaceae, Dipterocarpaceae, Euphorbiaceae, and Lauraceae. Ayyappan and Parthasarathy (1999) reported that the family Euphorbiaceae was the most dominant in terms of species richness and dominance, while the Dipterocarpaceae was due to its contribution to the basal area in the tropical evergreen forest of the Anamalais of the Western Ghats. The present study reveals that the families Euphorbiaceae, Clusiaceae, and Dipterocarpaceae are the most important in the wet evergreen forest of the Western Ghats.

The familial importance value index showed that Euphorbiaceae and Combretaceae were the dominant families in the moist deciduous forest of the present study. The families Combretaceae and Euphorbiaceae showed the highest importance value index in the tropical deciduous forest of the Eastern Ghats (Naidu and Kumar, 2015). Sundarapandian and Swamy (2000) also reported that the family Combretaceae is the most important in the moist deciduous forest of the Kodayar forest in the Western Ghats. A similar report by Pragasan and Parsatharathy (2010) in the Southern Western Ghats. A few other studies reported that the family Euphorbiaceae was the most diverse in tropical moist deciduous forests (Panda *et al*., 2013). This conformed with several other studies.

Kandi *et al.* (2011) reported the high family importance of Poaceae, Fabaceae, Euphorbiaceae, Combretaceae, Asteraceae, and Anacardiaceae in the deciduous forest of Sunebeda Wildlife Sanctuary. The family Combretaceae was reported to be the most important family out of the twenty-eight encountered in the tropical deciduous forest of Western India because of its higher familial importance and its species richness (Kumar *et al.,* 2010a). The family Euphorbiaceae was the dominant family in the mixed deciduous forest of the Darjeeling Himalaya (Shankar, 2001) and the co-dominant family in the *Shorea robusta* forest of West Bengal (Kushwaha and Nandy, 2012). The Euphorbiaceae and Dipterocarpaceae families contribute the most to the dominance of the forest community of evergreen and semi-evergreen forests.

Obviously, in the myristica swamp forest, the family Myristicaceae was dominant in the present study. The dominance of the Myristicaceae is mainly due to the high species richness of the constituent species; Dipterocarpaceae and Anacardiaceae were found to be the co-dominant families. Bhat and Kaveriappa (2009) also reported the Myristicaceae family as the dominant and Dipterocarpaceae and Celastraceae as the co-dominants in the Myristica swamp forest of Uttara Kannada, Karnataka, India. This showed the importance of the families Myristicaceae and Dipterocarpaceae in the myristica swamp forest.

Like other studies, Lauraceae is the most dominant family in a mountainous forest (Losos and Leight, 2004). The present study reported that the family Lauraceae is dominant in the hilltop tropical forest. Chen *et al.* (1997) reported that Lauraceae has the highest family importance index. Misra *et al*. (2005) also recorded the dominance of the family Lauraceae and the Euphorbiaceae as co-dominant in the humid subtropical forest of Meghalaya. Sellamuthu and Lalitha (2010) reported the families Lauraceae and Rubiaceae as the dominant in the montane wet temperate of the Southern Western Ghats region. Among the forest types in the present studies, it is important to note that some of the families of the dominant species, like Bombacaceae, were represented by only two or fewer species. Even though vegetation can be defined in terms of several quantitative parameters, such as frequency, density, and cover, the use of any one of these quantitative parameters may result in oversimplification or underestimation of the species' status (Kigomo *et al*., 1990; Oyun *et al*., 2009).

5.3.6. Species distribution pattern (AB/ F)

The pattern of species distribution in forest communities is measured as the ratio of abundance and frequency. The values ranged from 0.025, between 0.025 and 0.05 random, and a value > 0.05, showing the clumped or contagious pattern of species distribution (Curtis and Cottam 1956). The predominance of clumped dispersion of trees observed in the present investigation in most of the ecosystems in the current research is compatible with the results of various other studies in tropical forests (Parthasarathy and Karthikeyan, 1997a; Parthasarathy and Karthikeyan, 1997b). The random distribution pattern was rarely reported in semi-evergreen, moist deciduous, and myristica swamps, as reported in many other works in the tropical forests, regardless of the geographical regions (Armesto *et al*., 1986; Ayyappan and Pathasarathy, 1999). Sharma and Samant (2013) analyzed tree distribution patterns and observed regular, contagious, and random distribution in the Hirb and Shoja forests of the Northwestern Himalaya. Kumar and Bhatt (2006) observed that most of the species followed contagious distribution. Rao *et al.* (1990) also reported a similar pattern of species distribution. Ayyappan and Parthasarathy

(1999) observed both clumped, uniform, and random distribution in the tropical evergreens of Varagalaiar and Anamalais of the Western Ghats.

According to Richards *et al.* (1996), uneven dispersal of seeds could result in the clumped distribution of individuals of the same species. Similar to the spatial pattern of tree species distribution was reported in many tropical forest studies. The tropical evergreen species of the current study expressed a completely contagious distribution pattern of all the tree species, with no single species showing a uniform distribution pattern. According to Connell (1971), in the tropical forest, individuals adult trees could be uniformly distributed, and this type of distribution pattern enables the maintenance of high species diversity. However, it was emphasized that trees are generally more aggregated or randomly distributed in the tropical forest than in a uniform form of distribution (Forman and Hahn, 1980).

In the tropical semi-evergreen forests of the present study, 98 percent of the species showed a contagious distribution pattern, higher than the 61.8 percent in the semi-evergreens of Manipur (Devi and Yadava, 2006). Misra *et al.* (2005) reported that in the humid subtropical forest of Meghalaya, except for two species, all the other tree species followed a contagious distribution pattern.

The distribution of the species in the moist deciduous of the present study was recorded as more contagious than random or regular distribution. Of the fifty-eight species, fifty-seven are contagiously distributed, and only one species is randomly distributed. Sahu *et al*. (2012) recorded fifty-two species that showed contagious distribution and five species randomly distributed out of the fifty-seven species in the moist deciduous forest of Malyagiri in the Eastern Ghats region. The random distribution pattern is portrayed by species exposed to large recurrent disturbances (Armesto *et al*., 1986).

In the myristica swamp forest, few individuals show a regular pattern of distribution. The random distribution pattern of few species in the myristica swamp and moist deciduous forest may be due to the domination of a few species, whereas in the tropical semi-evergreen forest, it could be attributed to the differences in species domination across the strata. In a natural forest, habitat reported contagious and random species distribution patterns (Abhilash and Menon, 2009, Negi *et al*., 2018). Recently, Abhirami (2020) reported a contagious and uniform distribution pattern of species. The clumped or contagious pattern of species distribution portrays natural vegetation (Odum, 1971; Verma *et al.,* 1999). However, a few studies have reported regular tree distribution patterns in the evergreen, semi-evergreen, moist deciduous, and random patterns in the mangrove forest of Andaman (Padalia 2004). According to Looman (1979), in a given community, the pattern of species distribution depends partially on that habitat history and the species-specific attributes of that community. The uniform pattern of species distribution could result from direct competition of water or allelopathy (MacMahon and Schimpf, 1981), although tree aggregation can be triggered by seed dispersal (Parthasarathy and Karththikeyan 1997a) due to soil nutrient levels or other topographic features.

5.3.7. Species density and basal area

Individual species density is a quantifiable indicator of plant diversity (Watternberg, 1997). In the present study, the per hectare density of tree species varied significantly across the ecosystems, with the highest being 1144.44 ha^{-1} for the myristica Swamp forest, followed by the wet evergreen forest. The stand density (1054 ha^{-1}) of wet evergreen forest recorded in the present study is within the range reported (Bhuyan *et al*., 2003), higher than that reported by (Sankar and Sanalkumar, 1998; Varghese and Balasubramanyan, 1999; Swamy *et al*., 2010). However, the values were lower than those reported by Basha (1987), Pascal (1988), Giriraj *et al*. (2008). The tropical evergreen forest of Anamalais of the Western Ghats (Ayappan and Parthasarathy (1999) reported 456 stems ha^{-1}. This showed that the stand density recorded in the evergreen forest in the present study is within the medium range. However, the variation in altitude, temperature, humidity, topography, diameter class categories, and the sampling approach might have influenced this variation.

The stand density of the tropical semi-evergreen forest of the present study was 914.53 stems ha^{-1} which is comparatively higher than (568 stems ha^{-1}) as reported by Reddy *et al*., 2007). However, the values are within the range of (640-986 stems ha^{1}) Kadavul and Parathasarathy (1999). Bijalwan *et al*. (2009) studied the structure and diversity of the dry tropical forest of Chattisgarh. They reported that the number of trees in the overstorey varied from 553 to 842 stems ha^{1}. They observed that a higher number of species and diversity and dominance were recorded in the western aspect of the forest due to species regeneration and moisture conditions between the different aspects studied. A similar range was the value of 349 to 627 ha^{-1} reported by Singh and Singh (1991) in the Mirzapur district and is comparable to the investigation conducted in the moist deciduous of the Agasthyamalai region by Varghese and Menon (1998).

The stand density (876.97 stems ha^{-1}) of the tropical moist deciduous forest observed in the present study is higher than the range of values (Kumar *et al.,* 2010b; Panda *et al*., 2013; Reddy *et al*., 2007; Sahu *et al*., 2007; Naidu and Kumar, 2016; Sahoo *et al*., 2017; Sahoo *et al*., 2020). The density of tree species of 1144.44 ha^{-1} recorded in the myristica swamp forest of the current study was higher than reported (Varghese and Menon 1998; Sreejith *et al*., 2016) and lower than reported by Varghese and Kumar (1997). The density of the swamp forest of Shendurney is within the range reported elsewhere.

5.3.8. Basal Area cover

The basal area is an important indicator of growing stock and biomass production. The basal area recorded across the forest ecosystems of the Shendurney wildlife sanctuary varies significantly. It ranges from a high of 50.04 m^2 ha^{-1} in the evergreen forest to the lowest of 16.93 m^2 ha^{-1} in the hilltop forest (table 32). The basal area cover of 50.04 m^2 ha^{-1} for the tropical evergreen forest was comparably higher than in the mid-elevation forest of Sengaltheri KMTR (Ganesh *et al*., 1996), in the undisturbed wet evergreen forest of Kalakad KMTR (Parthasarathy, 2001), in the evergreen forest of Anamalais (Ayyappan and Parthasarathy, 1999), and in the Agambe rainforest of Western Ghats (Srinivas and Parthasarathy 2000) in Attapady region (Basha, 1987), of Kakachi-KMTR (Giriraj *et al.,* 2008), but lower than in the Nilambur region (Sanalkumar, 1997) and Agasthyamalai region of Kerala (Varghese and Balasubramanyan, 1999). The basal area cover reported from the present study is comparatively within the medium range of values reported by many studies in the evergreen forest of the Western Ghats. The relatively higher value of the basal area of tree species in the tropical evergreen forest could be attributed to the relatively higher number (109 species) of individuals in the higher girth class category of >210 cm. Ganesh *et al*. (1996) have attributed the higher basal area of tree species in the forest ecosystem to species with a girth class category of > 300 cm. However, altitude, species composition, age of the trees, degree of disturbances, and successional stage may also contribute to differences in basal area (Sundarapandian and Swamy, 2000). The higher basal area of tree species in the evergreen forest indicates the potential biomass aggregation and carbon storage of primary forest species.

The species basal area of 41.64 m^2 ha^{-1} of the tropical semi-evergreen recorded in the present study is higher than the range reported in the tropical semi-evergreen forest of Manipur by Devi and Yadava (2006) and comparably similar to 43.62 m^2 ha^{-1} (Reddy *et al*., 2007); 21.62-44.26 m^2 ha^{-1} (Kadavul and Parthasarathy, 1999; and lower than 58.0 m^2 ha^{-1} of the tropical semi-evergreen of HGWLS reported by Sakar and Devi (2014). The value reported in the present work is within the range reported elsewhere. In the moist deciduous forest, the basal area was 26.88 m^2 ha^{-1} comparatively lower than the ranges recorded (Reddy *et al.*, 2007; Murthy *et al*., 2016). Compared to the range reported (Sahoo *et al*., 2017; Saho *et al*., 2020) and higher than the range reported (Bijalwan *et al*., 2009; Panda *et al*., 2013). Therefore, the basal area reported in the present study is within the range reported in several studies in moist deciduous forests. Moreover, the relatively lower basal area cover reported in the deciduous forest could be attributed to the more significant proportion of 574 species (43.1%) of tree species belonging to the lower girth class category (10-30 cm) and a few (15 species) representing 1.1 % in the girth class category of >210 cm. The basal area of the myristica swamp forest reported in the current study is similar to 34.25 m^2 ha^{-1} (Sreejith *et al*., 2016), higher than 30.14 m^2 ha^{-1} (Varghese and Kumar, 1997) and lower than as reported by Varghese and Menon (1998).

In the tropical hilltop forest, the basal area reported was comparatively higher, 16.93 m^2 ha^{-1}, similar to the range of 9.3 m^2 ha^{-1} - 16.8 m^2 ha^{-1} in the hilltop forest of central Himalaya, higher than reported by Sagar *et al.* (2003) in the hills of Vindhyan. However, the value was lower than reported what is reported by Chen *et al.* (1997), Sundrapandian and Swamy (2000), and Jayakumar and Nair (2013). The current value reported in this work for tropical hilltop forests is comparably within the range reported for many hilltop forests. However, the values could be attributed to the forest's low density, shrubby, and open structure. In the Nilgiris, a montane evergreen forest, the ecosystem showed a high degree of dominance. Three species represented one-third of the total stem and a low degree of rarity (Mohandas and Davidar, 2009). Fifty-seven species of trees were recorded with a density of 832 stems ha^{-1} and 53.55 m^2 ha^{-1}. The study reported that the genus *Cinnomomum* had the highest species richness, followed by *Symplocos*, *Syzygium,* and *Litsea spp.* The study observed that Lauraceae has the maximum species richness, while Rubiaceae has the highest number of individuals, followed by Lauraceae and Myrtaceae. However, the percentage of species endemism to the Western Ghats was recorded at 37 percent.

The lower value of the basal area reported in some forest types could be linked to many smaller individuals of the dominant species. The difference in density and basal area across the forest types may be attributed to altitudinal variation, species composition, successional stage of the forest, level of disturbances, and species composition. This is consistent with (Swamy *et al*., 2000).

5.4. Cluster analysis and species association

The concept of ecosystem clustering analysis is to arrange the plots into groups based on their species compositional similarity as measured by chosen ecological distance. The cluster analysis furnishes a concise of the similarity in species composition of various study sites. Sites grouped into a single cluster have a similar composition than sites grouped into different clusters (Kindt and Coe, 2005). The cluster analysis gives out information vital for a better understanding of the species-site compositional similarities. The tropical evergreen forest cluster analysis showed an apparent group of clusters indicating species composition observed with altitude changes. In the evergreen forest, this cluster grouped the low elevation species, medium elevation, and higher elevation as the major groups and has demonstrated a change in plot similarities with elevation changes and an increase in decreasing compositional similarities with changes in elevation (Figure 5). A similar pattern of species compositional change was noticed in the hilltop forest (Figure 37). In semi-evergreen forests across the ecosystem strata studied, plots of similar species composition were reported to be grouped as a cluster (Figure 13). In the forest types of low altitude, like tropical moist deciduous, although the forest sites are found almost within similar altitudinal gradients, the cluster analysis has shown and grouped plots with similarities in composition. Similar composition and patterns were observed in the myristica swamp forest, found in the lower elevation gradient.

5.5. Species association in forest ecosystems

Species with similar ecological requirements and similar adaptation to the particular ecological unit can be found in an association. Liu *et al*. (2019) defined species association as an interrelationship of different species occupying a habitat. It is a static description of the connection established by the interaction of species and provides a scientific basis for species assemblage, which is vital for conservation and management. The present investigation examined the major species associations across the forest ecosystem types using the ordination technique, i.e., Detrended Correspondence Analysis (DCA). This technique geometrically arranges sites and species so that the distance between them illustrates the ecological distance.

Across the forest types of the current inventory, the detrended correspondence analysis DCA ordination of the species matrix has classified species into various assemblages. Different species assemblages were observed in the evergreen forest (figure 6), which revealed species coexistence and altitudinal formation. An assemblage of species like *Diospyros candolleana*, *Mesua ferrea*, *Cullenia exarillata*, *Vateria indica*, *Xanthaphyllum arnottianum*, *Baccaurea courtallensis*, and *Dysoxylum malabaricum* were reported. These assemblages are composed of many species that show a wider range of ecological distribution. Pascal (1988) identified an association of *Cullenia exarillata, Mesua ferrea,* and *Palaquium ellipticum* in the mid-elevation evergreen forest of the Western Ghats. *Bhesa indica*, *Measa indica,* and *Elaeocarpus munronii* were observed in association at higher altitudes. Similarly, a semi-evergreen forest represented by an assemblage of *Ixora brachiata, Tabernaemontana alternifolia*, *Aporosa cardiosperma*, *Diospyros candolleana, Artocarpus hirsutus, Lagerstroemia microcarpa, Litsea coriacea, Grewia tiliifolia* were reported.

An assemblage of *Turpania malabarica*, *Aglaia bourdillonii, Syzygium densiflorum,* and *Syzgium caryophyllatum* were reported in the hilltop forest in the current study. Pascal *et al*. (2004) have similarly reported an association of *Aglaia bourdillonii* and *Syzygium spp* in the Western Ghats region. The literature on species association of the forest ecosystem of the Western Ghats was found rare for comparison with the current inventory.

5.6. Proportion of endemic and threatened trees species

The Western Ghats, to which the forest of Kerala belongs, are one of India's three biodiversity hotspots and one of the world's ten mega biodiversity hotspots (Nayar, 1996). The Western Ghats are also home to many endemic species. The flowering plant taxa of the Western Ghats are one of the world's 34 hotspots, with a total of 4000 species, with 1500 endemics (Nayar, 1996). Endemic taxa have limited distribution or narrow geographical ranges (Fjeldsa, 1994) and consequently need conservation priority. The study of species endemism and why it occurs is getting increasing concern in many biodiversity studies and is considered paramount for biodiversity conservation. In the present study, the total percent composition of endemic species of the tropical evergreen forest was 55.58% (Fig. 42), higher than the 51% reported for Kakachi KMTR (Giriraj *et al.,* 2008). According to Ramesh and Pascal (1997) of the Southern Western Ghats, endemism could be as high as 63 percent. Vimhaseno and Nagaraja (2019) have recorded 26 tree species from 68 species in the Western Ghats region. Ramesh and Pascal (1997) observed that nearly sixty-three percent of woody species are the Western Ghats endemic. In the evergreen forest of the Western Ghats, tree species contribute significantly to endemism in the region. Ganesh *et al*. (1996) reported a high (62.5%) percentage of endemism in the Kalakad Mudanthurai Tiger Reserve of the Western Ghats. Ramachandran and Swarupanandan (2013) recorded 34 percent endemism from the Nellianphathy Southern Western Ghats. The degree of endemism in the southern Western Ghats region could be attributed to the intensity of rainfall. Nayar (1997) stated that the species endemism of a particular geographical region manifests the biogeography of that area, the center of speciation and adaptation. In a study conducted in the Andaman region, Padalia (2004) reported that out of the 369 tree species recorded, 41 (11.11%) are endemic, and 28 are rare species. In the present study, the myristica swamp forest expressed a high degree of endemism, 85.55% higher than the 36.50% reported in the swamp of Uttara Kannada (Bhat and Kaveriappa, 2009). In the hilltop forest of the present study, a high percent (79.15%) of the level of endemism was reported (figure 42). This value was significantly higher than the 30 percent reported by Sellamuthu and Lalitha (2010) in the wet montane temperate of the southern Western Ghats. Sellamuthu and Lalitha (2010) recorded about 67 tree species constituted of 30 percent endemism in the montane wet temperate of the Southern Western Ghats region. According to Subramanyan and Nayar (1974), a higher degree of endemism in the Western Ghats can be attributed to the general prevalence of endemism among the tree species of the hilltop forest of the Western Ghats. This may be attributed to the overall prevalence of endemism among tree species in the hilltop flora of the Western Ghats (Subramanyan and Nayar, 1974).

Based on threatened categories of the tree species across the five forest types, a high percent (21.21%) of the endangered species were observed in the Myristica swamp forest, followed by 15.91% in the tropical hilltop forest and the lowest value (1.72%) for the tropical moist deciduous forest. The degree of vulnerability of species to extinction in the future was recorded at the highest (22.73%) in the tropical hilltop forest, followed by the (18.18%) for the Myristica swamp forest and the lowest (6.90 %) for the tropical moist deciduous forest, respectively.

5.7. Regeneration of trees in the forest ecosystems

Forest wealth is determined by the future regenerative status of the species that make up the forest stand (Jones *et al*., 1994). Understanding the processes that impact tropical forest species regeneration is important for both ecologists and forest managers. Bhuyan *et al*. (2003) defined regeneration as the silvigenesis process by which trees survive over a period of time. A unifying model of the silvigenitic cycle was proposed by Halle *et al*. (2012), which defines a forest as a dynamic system with successional consequences of ever-changing composition and structure; a dynamic, growing phase follows a stable homeostatic phase after a smaller or larger breakdown of forest structure.

However, the potential of species to regenerate define and measure the wellbeing of the forest. And that in any tree community, the presence of seedlings and saplings of the trees often indicates effective regeneration (Saxena and Singh, 1984). Natural and anthropogenic factors significantly affect the species number, density, and potential regeneration (Bhat *et al*., 2000; Murthy *et al*., 2002). Poor soil nutrient availability also affects species regeneration potential (Inuwa and Bilyaminu, 2020). Many studies in Western Ghats forests recorded poor regeneration (Sukumar *et al*., 1992; Murali *et al*., 1996). The density and pattern of distribution of the regenerating tree species vary significantly across all the forest ecosystems. The density of regenerating seedlings and saplings species in the present study portrayed different categories of community structure among all the forest types, with changes noticed in some of the forest community while others have maintained their dominant community with higher regeneration of the dominant species; community with higher regeneration of the co-dominant species as well as the community with a mixture of species that displayed higher regeneration of one of the dominant species. A similar change in forest community structure was reported in Hirb and Shoja of Northwestern Himalaya (Sharma and Samant, 2013).

In the current investigation, the potential of species regeneration of forest ecosystems of Shendurney was attempted. The result indicated differences between the saplings' and seedlings' demography of the tree species across the forest ecosystems. Species differ in the abundance of their saplings and seedlings, which may be due to differences in the stand's canopy structure and microclimatic conditions (Debb and Sundriyal, 2008). The overall species regeneration of the forest ecosystems of Shendurney is relatively high than other forests elsewhere. Shendurney wildlife sanctuary, being the protected area where human activities are strictly prohibited and monitored, tree falling and other forest operations are strictly proscribed. This gave a potential advantage to the regenerating species. However, altitudinal variation, soil characteristics, high precipitation, and moderate temperature promote a favorable environment for luxuriant growth in most of the forests of Shendurney Wildlife Sanctuary.

Across the forest types of the current study, some species were reported in the regeneration stage, not recorded in the tree stratum. The varied floristic composition of the tree canopy, saplings, and seedlings were reported in many studies of the tropical forest ecosystems (Uhl *et al*, 1981; Jones *et al.,* 1994). Though many studies in the Western Ghats are reported to have poor regeneration (Sukumar *et al*., 1992), in almost all the forests of Shendurney, the dominant tree species displayed an adequate regeneration at the saplings and seedlings stage. However, the lower representation of saplings of some tree species in the current investigation agrees with the observation of Sundarapandian and Swamy, 1998; Swaine and Hall, 1988). The existence of adequate population of seedlings, saplings, and adults for most of the forest ecosystems reported in this study indicates successful regeneration of forest tree species, and the presence of saplings under the canopies of adult trees indicates the potential composition of a community (Saxena and Singh, 1984; Pokhriyal *et al*., 2010).

In the current study, three groups of species were identified after comparing seedlings, saplings, and adult populations of tree species: individuals found only as mature trees and /or saplings without seedling, individuals as mature trees, saplings, and seedling, and individual as seedlings only. Chandrashekara and Ramakrishnan (1994) reported a similar trend in the species pattern of the establishment. Some species were absent in the sapling stage. However, some exist in the seedling stage and with poor density. According to Sapkota *et al*. (2009), this pattern of species distribution could be attributed to the high degree of light demand of the species. A relatively higher density of species was observed, which later declined subsequently in the saplings stage.

5.7.1. Structural composition of seedlings and saplings

The present study showed that seedlings had a good representation of the most dominant tree species across the forest ecosystem. The highest tree seedlings density 2777.77 ha^{1} reported for the tropical evergreen forest. The seedlings density in the tropical evergreen forest was reported by Chandrashekara and Ramakrishnan (1994), Nath *et al*. (2005), Jayakumar and Nair (2013). In the semi-evergreen forest, the seedlings density 25833.33 ha^{1} reported in the present investigation is higher than reported in the semi-evergreen of Manipur (Devi and Yadava, 2006; Jayakumar and Nair, 2013). The present work recorded 19083.33 ha^{1} seedlings in the moist deciduous forest, comparable to the range reported (Sahoo *et al.,* 2017) and significantly higher than the density reported by Jayakumar and Nair (2013).

The density of saplings among the forest types was observed higher (3581.40 ha^{-1}) in the evergreen forest and the lowest (2448 ha^{-1}) for the myristica swamp forest. The density of saplings was comparably higher than that reported in the evergreen forest of Nelliamphathy of Western Ghats (Chandrashekara and Ramakrishnan, 1994); in the undisturbed evergreen forest of Namdapha National Park (Nath *et al*., 2005); and tropical forest of Western Ghats (Jayakumar and Nair, 2013). The saplings density of 2931.91 ha^{-1} reported in the semi-evergreen forest is higher than that reported by Devi and Yadava (2006) in Manipur and Jayakumar and Nair (2013). In the deciduous forest, the saplings density 2810.39 ha^{-1} reported in the current study was comparatively similar to the range reported by Sahoo *et al.* (2017) in the moist deciduous forest of Eastern India, higher than reported by Jayakumar and Nair (2013) in the tropical deciduous forest of Western Ghats region. Compared to the density of seedlings and saplings with that of adults, the adult population was reported to be disproportionately low across the forest ecosystems for most of the species. The variation in density of seedlings and saplings with the other studies could be due to differences in the methodological approach adopted and the diameter size of the regenerating species. However, this study observed that most of the dominant species are adequately represented at the sapling and seedling stage for most of the forest ecosystems.

5.7.2. Saplings and seedlings diversity

The diversity of regenerating species was studied and reported among all the forest types of the current investigation. The highest 3.96 Shannon H value for saplings was recorded for the semi-evergreen forest (table 12). The lowest value, 2.97, was reported for the saplings of the myristica swamp forest (table 24 and figure 33). The higher 3.88 value was recorded in tree seedlings of evergreen forest (Table 6). The Shannon H index value for regenerating species of the evergreen forest was 3.92 for saplings and 3.82 for seedlings, with the higher value recorded for saplings. In the semi-evergreen forest, the value of the Shannon index of saplings and seedlings reported in the current study was higher than 3.09 and 3.49 reported in the tropical evergreen forest of the Western Ghats region (Jayakumar and Nair, 2013). The Shannon index of seedlings and saplings of the semi-evergreen forest in the present study was higher than 1.31 and 1.33 reported by Devi and Yadava (2006) in the semi-evergreen forest of Manipur North India. Similar to that reported (Jayakumar and Nair, 2013). In the moist deciduous forest, the value Shannon of 2.48 and 2.62 for the saplings and seedlings reported by Jayakumar and Nair (2013) were comparably similar to the finding of the present study. In the myristica swamp forest, the Shannon index of saplings and seedlings is higher than for the tree species, which could be due to the sensitivity of the Shannon index to rare and single or few species domination. Devi and Yadava (2006) have reported a similar pattern of diversity. The difference in the diversity index compared to other studies could be associated with the variations in species richness, the pattern of distribution, and the degree of dominance of the species. The range of the Shannon-weaner diversity index reported in the present work is relatively higher than reported by many authors (Chandrashekara and Ramakrishnan 1994, Abhilash *et al*., 2005, Devi and Yadava, 2006). The higher diversity index is manifesting a favorable condition for the ecological process. According to Anitha *et al*. (2010), the higher diversity of regenerating species is an important parameter in assessing the ecological condition of a particular forest ecosystem and vital for understanding the extent of ecological processes like dispersion of seed and pollination.

The concentration dominance (Simpson index) of saplings and seedlings among the forest types was estimated. Across the forest types, the highest (0.97) Simpson index of diversity for saplings was recorded for evergreen and semi-evergreen, and the lowest (0.93) value was reported for moist deciduous and the myristica swamp forest. The highest value of tree seedlings species (0.97) was observed for evergreen forest and the lowest (0.91) for myristica swamp forest. The Simpson index for the regenerating saplings and seedlings species of evergreen in the present study was higher than 0.89 and 0.87 reported by Chandrashekera and Ramkrishnan (1994) in the present study wet evergreen forest of the Western Ghats region. For the semi-evergreen forest of the current study, the Simpson index of diversity was higher than 0.71 and 0.73 for saplings and 0.46 and 0.45 for seedlings reported by Devi and Yadava (2006).

The Margalef value of the regenerating species was higher for saplings (14.14) in the evergreen forest. The lowest (5.62) was recorded for the saplings in the myristica swamp forest and a similar trend in seedlings (13.54) for evergreen and myristica swamp forest (5.42). The lower value of Margalef in the myristica swamp could be due to the smaller sampling area. However, the sampling for the semi-evergreen forest is relatively higher than that of the evergreen forest; hence the Margalef value is higher for the evergreen forest. In these circumstances, the higher value of Margalef in the evergreen forest could be due to the higher species richness. The Margalef index reported in the current study for the evergreen forest is comparably higher than recently reported by Abhirami (2020).

5.7.3. Phytosociological analysis of the regenerating species

Tropical forests showed variation in regeneration patterns due to differences in constituent species and the environmental variables they grow (Kyereth *et al*., 1999). The phytosociological observation of the saplings and seedlings was estimated for all the forest types. The pattern of distribution and domination of the dominant and co-dominant varies significantly in most of the forests of the current study. Some of the dominant species are maintained at the saplings and /or seedlings stage. The dominance of *Mesua ferrea* in the evergreen forest observed in both the saplings and seedlings stages could be due to the higher ecological amplitude and wide range of adaptation across the elevation gradients. The co-dominant in saplings are *Dysoxylum malabaricum* and *Xanthophyllum arnottianum.* The saplings of the most dominant species, including *Cullenia exarillata* have shown good regeneration capacity. Contrary to Abhirami (2020) finding, the current study reported good regeneration of the *Cullenia exarillata* at the sapling stage. This could be attributed to the unimpaired nature of its ecological distribution, as most of its distribution was noticed in the core zone area, where human activities are strictly restricted.

In the semi-evergreen forest, the dominant saplings recorded are *Xanthophyllum arnottianum* and *Hopea parvifolia,* while in the seedlings stage, *Cinnomomum malabatrum* and *Hopea parviflora* are the dominant species. Most of the dominant and co-dominant tree species of semi-evergreen have shown good regeneration at the sapling stage. The dominant saplings in the moist deciduous forest are *Aporosa cardiosperma* and *Olea dioca,* and *Mallotus tetracoccus* and *Tabernamntana alternifolia* at the seedlings stage. In myristica swamp forest, the dominant species at the sapling stage are *Knema attenuata*, *Gymnacranthera furquahariana,* and *Myristica dactyloides*, the co-dominants tree species are found to be the dominant saplings in the swamp. The seedlings are dominated by *Myristica dactyloides*, *Cinnomomum malabatrum,* and *Knema attenuata*. In the tropical hilltop forest, the dominant saplings recorded are *Cinnomomun sulpharatum* and *Litsea floribunda*. At the seedling stage, *Litsea floribunda* and *Ardisia rhomboidea*.

The seedlings and saplings of emergent species indicated that they are appropriately regenerating throughout the forest despite the intense competition from the sub-canopy layer. Most of the dominant species across the forest ecosystem in the current study have shown relatively good regeneration. Some individuals dominate at both saplings and seedlings. The seedlings and saplings growing close to the mother plant depicted the nature of the natural forest. These observations are similar to several ecological studies elsewhere (Armesto and Fuentes, 1988; Al-Amin *et al*., 2004; Giliba *et al*., 2011; Deka *et al*., 2012). However, the current inventory observed the absence of some species at the seedling and/or sapling stage (Jayakumar and Nair, 2013) reported a similar pattern in his study on six different forest types of the tropical forests in the Western Ghats. The introduction of recruit species that were not found at the tree stage was noticed across forest types. The lack of trees representation in the saplings and seedlings stage could be due to poor regeneration potential of the species, the rarity of the species due to the sampling approach that involves taking some plots across the forest strata, or due to small sampling size.

The ratio of abundance to frequency (AB/F) evaluates the different species distribution patterns in a particular floristic community. The abundance-frequency ratio of saplings and seedlings of the forest type in the current inventory has reported a community of species manifesting a contagious, regular distribution pattern. The saplings and seedlings of the semi-evergreen, tropical hilltop and the seedlings of all the forest types have shown a contagious pattern of species distribution, indicating the broader distribution of the species across the forest ecosystems. The contagious pattern of species distribution manifests the natural vegetation (Verma *et al*., 1999). However, some of the tree saplings of evergreen, moist deciduous, and Myristica swamp forests have shown a random distribution pattern. Sharma and Samant (2013) have observed regular, contagious, and random distribution in their study. In a tropical forest, species are generally randomly than uniformly distributed (Forman and Hahn, 1980).

5.8. Soil Physicochemical Attributes

The fact that soil and vegetation grow together over time, the selective absorption of nutrient elements by different tree species, and their ability to return them to the soil causes changes in soil properties (Singh *et al*., 1986). The physical properties of soil are greatly influenced by vegetation. The soil structure, infiltration rate, water-holding capability, hydraulic conductivity, and aeration are all improved by the vegetation (Ilorker and Toley, 2001). The soil's nutrient status is determined by its physicochemical properties, which differ depending on climate, parent materials, physiographic location, and vegetation (Behari *et al*., 2004). The site potential of rainforests can be predicted with a reasonable degree of accuracy if specific physical and chemical soil properties are known (Tracey, 1969). However, some of the investigations in the tropical forest found that species composition is comparatively insensitive to soil characteristics (Hewetson, 1956; Schulz, 1960; Tracey, 1969; Knight, 1975).

Forest soil is subject to various changes across the spatial and temporal scales. It is crucial to survival and the potential for plant growth and individual plants' distribution in the forest ecosystems (Bharali *et al*., 2014). Therefore, vegetation studies are considered incomplete without incorporating it with the edaphic attributes studies; this is because the soil is an indicator that determines the type of vegetation of a particular geographical region. Physicochemical characteristics of forest soil significantly influence the potential development and growth of vegetation directly or indirectly. The soil and plant association has been studied and recognized as paramount to understanding the structure and pattern of vegetation growth and development. Several such studies are carried out in the Western Ghats region (Swamy and Proctor, 1994). The present studies investigated various soil physicochemical properties of the primary forest ecosystems of Shendurney wildlife sanctuary, intending to understand the interaction between vegetation and soil. The investigation revealed that the soil of the sanctuary is loamy and slightly acidic with relatively moderate physicochemical characteristics. The literature that compared physicochemical properties of soil of different ecosystems similar to this study is scarce and difficult to get; therefore, different forest ecosystems are discussed separately and compared with other similar ecosystems elsewhere. The discussions in this study are presented here below:

5.8.1. Cation Exchange Capacity (CEC)

The cation exchange capacity (CEC) is a measure of the total negative soil charges that adsorb plant nutrients cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}). The CEC is the property that describes the potential of soil to supply nutrient cations to soil solution for plant uptake (Sonon *et al.,* 2014). Virtually all the essential nutrients utilizing by the plant are in their ionic state from the soil solution (Robertson *et al.,* 1999). Therefore, understanding the proportion and the content of the solution and the nutrient inflow is paramount to the knowledge of the soil nutrients and other biogeochemical processes. In this study, the value of cation exchange capacity was reported ranged between 3.73 (cmol kg^{-1}) to 12.25 (cmol kg^{-1}), and varied with the soil depth levels. Among all the forest ecosystem types studied, tropical hilltop forests showed the highest cation exchange capacity (Table 33 and figure 45). The soil at higher altitudes has a better structure and higher cation exchange capacity (Mandal *et al.,* 1990). Giriraj *et al.* (2008) recorded a CEC value of 6.76 cmol Kg^{-1} in the wet evergreen forest of Kakachi KMTR, which is slightly lower than the 7.86 cmol Kg^{-1} recorded for the first horizon and slightly higher than the 6.08 cmol Kg^{-1} for the second horizon of the evergreen forest of the present study. In the present study, except for tropical semi-evergreen with slight fluctuation, the CEC showed a general decreasing trend down to the profile (Table 33 and figure 46). A similar pattern was reported in the evergreen forest (Balagopolan and Jose, 1995), in temperate acidic forest soil (Matschonat and Vogt, 1997), in forest soil of southern China (Dai *et al*., 1998).

5.8.2. Soil Organic Carbon

Soil organic carbon (OC) is crucial for the sustenance of vegetation growth. It is directly associated with soil organic matter content, which is the primary source of fertility in soil (Jobbágy and Jackson, 2000). The present study showed significant variation in the soil organic carbon across the five forest types. Soil organic carbon pool was highest at higher altitudes (Balagopolan and Jose, 1995; Bharali *et al*., 2014) and decreased with increasing soil depth (Jehangir *et al.,* 2012; Gosain, 2016; Tashi *et al.,* 2016). As expected, across all the forest ecosystems of Shendurney, the percentage of organic carbon is higher in the organic layer and showed a decreasing trend downward (Table 34 and figure 47). The present study reported that the value of percent organic carbon ranged between 0.46 % to 2.87 % and showed a decreasing trend with the increasing soil depth for all the ecosystems (Table 34). According to Maro *et al.* (1993), soil organic carbon is more on the surface layer and generally decreases with increasing depth.

Divya *et al.* (2016) reported an increasing trend in the soil organic carbon with altitudinal increase and decreasing with depth in the soil of the Western Ghats region. The present study reported the increasing trend in percent soil organic carbon from lower elevation to the higher elevation and decreased with increasing soil depth. The study reported a higher percent organic carbon in the tropical hilltop and west coast tropical evergreen forest, which are higher altitude forests (Table 34). The percent organic carbon reported in the hilltop forest was found comparably similar range (0.8%-2.3%) reported in the hilltop forest of central Himalaya (Khera *et al*., 2001). The semi-evergreen forest of Eastern Ghats (Kadavul and Parthasarathy, 1999) reported a decreasing trend of organic carbon. Khera *et al*. (2001) observed increasing percent organic carbon with increasing altitude in the mid-elevation forest of central Himalaya. Tsui *et al.* (2004) reported a similar trend of percent organic carbon. The increase in the soil organic carbon with altitude could be due to the high quality of the forest litterfall and slower decomposition rate in the higher elevation. Forming a highly dense canopy structure and relatively thick vegetation resulted in a high degree of carbon return due to the extent of litterfall in tropical forests (Saenger and Snedaker 1993; Divya *et al*. 2016).

Gairola *et al*. (2012) reported a decreasing trend of percent organic carbon with increasing depth in the moist temperate forest of Garhwal Himalaya. Similarly, roots structure, species composition, high rainfall, temperature, humidity, and pattern of litter decomposition could be the significant reason for high soil organic carbon in forest types of the current investigation.

5.8.2. Soil bulk density

Bulk density is an important soil physical attribute that measures soil compaction, an essential parameter for forest tree species growth, survival (Whalley *et al*., 1995), and soil productivity (Powers, 1991). In the present study, the soil bulk density showed significant variation across the soil depths and forest ecosystem types, with values ranging between 0.96 gcm^{-3} to 1.87 gcm^{-3} (Tab. 36). The bulk density showed an increasing trend with an increase in depth across all the forest ecosystem types; this could be due to soil compaction down to the profile. Bharali *et al.* (2014), Dar *et al.* (2015), and Misra *et al*. (2017) reported a similar decrease in bulk density with increasing depth levels in their edaphic studies. Across all the ecosystems, the bulk density is lower in the surface layer. According to Aweto (1981), the lower value of bulk density in the surface layer is due to the high concentration of root in the surface, which loosens the soil particles. Strong and La Roi (1985) have a similar view on bulk density. However, the present study reported lower bulk density in southern hilltop tropical forest and west coast tropical evergreen forest due to an organic matter layer and a slower decomposition rate at higher altitudes. Lower bulk density could also be attributed to the organic matter in the two forest ecosystems because bulk density is usually correlated to soil organic matter (Alexender, 1980; Handayani *et al*., 2012). Myristica swamp exhibited a higher bulk density value, which may be due to the higher clay mineral content in the soil. The bulk density for the evergreen forest was reported within the range of 1.23 gcm^{-3} to 1.43 gcm^{-3} (Balagopalan and Jose, 1993) within the range of 1.15gcm^{-3} 1.42 gcm^{-3} obtained for the west coast tropical evergreen forest of the present study. This study observed that bulk density value ranged between 1.29 gcm^{-3} to 1.5 gcm^{-3} for west coast tropical semi-evergreen forest, which is similar to 1.05 gcm^{-3} to 1.10 gcm^{-3} recorded in the semi-evergreen forest (Misra *et al*., 2017). In natural forest converted to the plantation in the moist deciduous forest zone, bulk density at 0-20 cm depth significantly increased from 1.17 gcm^{-3} to 1.30 gcm^{-3} (Amponsah and Meyer, 2000), which is similar to the value of bulk density obtained for southern secondary moist deciduous forest at the 0-10 cm soil depth for the present study.

5.8.3. Electrical conductivity

Electrical conductivity is a vital soil chemical property that relatively measures the soil's total quantity of ions. Electrical conductivity varies with the precipitation and drainage pattern of the site (Peverill *et al.,* 1999). The value of the soil electrical conductivity in the present study ranged between 0.084 dSm^{-1} to 0.93 dSm^{-1} and varied with the soil depth levels and ecosystem types. For example, the EC value of the wet evergreen forest of Kakachi KMTR was recorded 0.25 dSm^{-1} lower than 0.56 dSm^{-1} for the first horizon and similar to 0.26 dSm^{-1} of the second horizon in the present study (Ganesh *et al.* 1996).

Overall, the electrical conductivity showed a decreasing trend in the four different depths with increasing depth in southern tropical hilltop, west coast tropical evergreen, and west coast tropical semi-evergreen forests. This could be attributed to the high leaching of the soil nutrients from the surface layer due to high rainfall. Jehangir *et al.* (2012) and Dar *et al.* (2015) reported a similar decrease in electrical conductivity with an increase in depth. However, in the southern secondary moist deciduous and myristica swamp forest, there is no specific trend in electrical conductivity with increasing soil depth, and the values showed a significant increase in the third horizon. Similarly, in the myristica swamp slight increase in electrical conductivity was also observed. These may be attributed to the clay minerals leaching from the surface layer and deposition in the lower layers. Across the forest ecosystems, higher value electrical conductivity was observed in southern tropical hilltop and west coast tropical evergreen forest compared to a lower for west coast tropical semi-evergreen, southern secondary moist deciduous, and myristica swamp forest. The lower electrical conductivity recorded may be associated with a minor release of ions from mineral weathering influenced by the different temperature and moisture regimes (Kaushal *et al*., 1997).

5.8.4. Soil pH

Soil hydrogen ion concentration (pH) is an important soil property that measures the soil solution's hydrogen ion activity. Soil pH directly impacts plant nutrients' availability and is a good indicator of forest fertility (Black, 1968). Across all the forest ecosystems of Shendurney wildlife sanctuary, the soil was observed to be slightly acidic. According to (Leskiw, 1988), the soil should be slightly acidic in forest ecosystem to manage and control nutrient supply balance. Commonly, fertile soil has a pH value within the range of 5.5 to 7.2, and this would enable the fundamental nutrients and essential elements accessible for plant utilization (Gairola *et al*., 2012). In this study, the value of soil pH ranged between 5.28-5.43 for west coast tropical semi-evergreen, 5.10-5.47 for west coast tropical evergreen, 4.91-5.69 for southern moist deciduous, 5.39-5.67 for myristica swamp, and 5.00 to 5.44 for southern tropical hilltop forest respectively (Table 37 and figure 49). Balagapolan and Jose (1995) reported similar observations while comparing the natural evergreen forest and plantation soil characteristics. The lower value of soil pH in most of the sanctuary forest ecosystems could be associated with the contribution of the forest soil organic matter content and the soil's unruffled nature and high rainfall, which leads to the continuous leaching of the exchangeable soil bases (Paul, 2013). There is no general trend in the soil pH pattern across the depths for west coast tropical semi-evergreen forest, west coast tropical evergreen, southern moist deciduous, and myristica swamp forest. Contrarily, a decreasing trend was observed in the tropical hilltop forest (figure 49). High nutrient leaching bases and silica and deposition of laterite attributed to high rainfall could be the reason for the decreasing hydrogen ion concentration in the high altitude forest. Honey (2020) recently reported a similar trend on soil pH.

The high clay and the low nutrient content coupled with moderate acidity to neutral in myristica swamp forest could be attributed to the constant waterlogging. Varghese and Kumar (1997) and Ponnanperuma (1984) have a similar view of the myristica swamp forest soil. The lower organic carbon, electrical conductivity, cation exchange capacity content in the myristica swamp soil compared to the other forest ecosystems in the Western Ghats was supported by Jose *et al*. (1994) and Varghese and Kumar (1997), and Bhat and Kaveriappa (2009). The variation or changes in the water table, high rainfall, and the attributes of the swamp could be responsible for the low nutrients in the soil.

5.9. Forest land cover changes and Mapping

Land use and cover change have become paramount for better understanding and proper planning of problems associated with productive ecosystems and biodiversity, environmental degradation, wetland deterioration, loss of aquatic organisms, and wildlife habitat (Mallupattu and Reddy, 2013). The Earth Resources Technology Satellite, which was later named Landsat-1, was launched in early 1972. Satellite remote sensing provided potential benefits in assessing, planning, and monitoring natural resources (Roy *et al*., 1985; Kushwaha and Madhavan, 1989). Its ability to provide real-time data with contemporaneous and repetitive coverage provides distinct advantages over conventional methods. There is a common belief that forests in the Western Ghats are gradually shrinking due to increasing biotic impacts. Therefore, studying forest land use/forest cover (LU/LC) changes is very important for proper planning, managing, and utilizing natural resources. This particular study was undertaken to evaluate the extent of changes in different forest cover from 2001 to 2018 and show the use of multispectral Landsat data for identification, mapping, and change detection of Shendurney Wildlife Sanctuary in southern Western Ghats, Kerala, India.

Similar to other findings of the Western Ghats forest, the present studies on spatial variability of different ecosystem types of Shendurney wildlife sanctuary depicted that the forest is going through a gradual decrease with time. The tremendous decline in the major two forest ecosystems and the relatively insignificant gain in the West coast tropical evergreen forest and Southern tropical hilltop forest, contrary to the findings of (Kushwaha 1990) in which he reported the 5.66 % overall decrease with zero gain in the forest ecosystems types over twelve years. However, the considerable increase in the degraded forest defines the entire Sanctuary's future and its proximity to anthropogenic disturbance and other impacts associated with climate change. Kushwaha (1990), in his work on forest type and change detection, reported a significant increase in the degraded forest in Karnataka. The west coast tropical evergreen and southern tropical hilltop is virtually secured and relatively stable and showed significant increases in its extent (figure 61 and 62). This may be due to its terrain and inaccessibility, unlike the west coast tropical semi-evergreen and southern secondary moist deciduous forest, which is mostly low elevation forest and close to human settlements, making them easily accessible and facing different kinds of disturbances. The increase in the extent of the degraded forest could be attributed to the expansion in the human settlements in many part of the wildlife sanctuary and pressure on the demand for agricultural land by the inhabitants. The rapid growth of the human population close to forest ecosystems has increased the risk of degradation and fragmentation (FAO, 2001). In Lombok eastern Indonesia, Kim (2016) reported a significant decrease in the extent of the forest land for the 20 years time interval. However, there was no apparent reason for the drastic reduction during the research time. He presumably attributed the loss to timber extraction, the pressure on land for agriculture and urban development, and poor governance institutions (Curran *et al*., 2004).

Land use and land cover change are not random and not constant spatially and temporally (Lira *et al*., 2012) studied the effect of LULCC on size, shape, and degree of forest patches isolation. They found a significant increase in forest patches when deforestation outpaced forest regeneration and a significant decrease when forest regeneration outpaced deforestation. Kushwaha (1989) reported a marginal increase in the water body area. Contrary to the present study, despite the ongoing rehabilitation of the Thenmala Dam, the study reported a decreasing trend in the water body. Due to varying precipitation and temperature, the size of the water body can change from year to year. Toorahi and Rai (2011) have a similar view on water body fluctuation in their study.

Poor forest management practices like forest fire management may increase the degree of open and degraded forest in the wildlife sanctuary. The strata formation of forest ecosystem types of Shendurney rendered it proximate to fragmentation and susceptible to anthropogenic disturbances. Most of the forest ecosystems of Shendurney were found to be in the form of strata, especially the moist deciduous, semi-evergreen, and myristica swamp forest. According to Ewers and Didham (2006), edge effects are more common in forest patches with irregular shapes than in patches with more compact shapes. They have been impacted negatively on many species (Ewer and Didham, 2006). The land cover of Shendurney Wildlife Sanctuary is reported changing. The main change observed in the Shendurney wildlife sanctuary was the significant increase in degraded forests, the decline in the extent of moist deciduous forests, semi-evergreen forests, and little gain in evergreen forests. The apparent changes in the forest ecosystems of Shendurney Wildlife Sanctuary reported in the present investigation are important phenomena requiring urgent and compelling managerial action to sustainably monitor various human activities, which are considered the prominent change actors. However, improving the living standard of the forest fringe community should be given a priority.

Summary

SUMMARY

The study entitled "Phytosociological and edaphic attributes of forest ecosystem of Shendurney Wildlife Sanctuary, Kollam, Kerala" was carried out to evaluate the phytosociological attributes of different forest ecosystems and to analyze the physicochemical attributes of soils of different forest ecosystems. The study also aimed to understand the land use and land cover change of the forest ecosystem of Shendurney Wildlife sanctuary. The result obtained from this investigation are summarised below:

1. In the forest ecosystem types of Shendurney wildlife sanctuary, the species richness was found higher in the west coast tropical evergreen forest with 119 tree species, followed by 101 species for the west coast tropical semi-evergreen forest, 58 species in the moist deciduous forest, 44 species for the tropical hilltop forest. The lowest species richness of 33 species was reported for the myristica swamp forest.
2. The higher species endemism of 85.44% was recorded in the myristica swamp forest, followed by 79.15% for the tropical hilltop forest, 55.58% for the west coast tropical evergreen forest, 40.71% for the west coast tropical semi-evergreen forest, whereas the lowest percent endemism of 29.26 % was reported for the moist deciduous forest respectively.
3. The density of the tree species per hectare was found higher in the myristica swamp 1144.44 ha^{-1}, 1053.50 ha^{-1} for west coast tropical evergreen forest, 914.55 ha^{-1} for the west coast tropical semi-evergreen, 876.97 ha^{-1} for the moist deciduous forest, and lowest density of 619.00 ha^{1} was recorded for the tropical hilltop forest respectively.
4. The stand basal area was significantly higher, 50.04 m^{2} ha^{-1} in the west coast evergreen forest, followed by the 41.64 m^{2} ha^{-1} for the west coast tropical semi-evergreen forest, 33.93 m^{2} ha^{-1} recorded for myristica swamp, 26.88 m^{2} ha^{-1} for the moist deciduous forest, and lowest value of 16.93 m^{2} ha^{-1} reported for the tropical hilltop forest.
5. The girth class distribution of the forest ecosystems of Shendurney varies significantly, with the west coast tropical evergreen forest showed the

reversed J-shaped distribution. In the west coast, semi-evergreen and secondary moist deciduous forests showed a completely L-shaped distribution. In the tropical hilltop forest, the reversed iJ shape was reported, respectively.

6. The dominant species recorded in the west coast tropical evergreen are *Mesua ferrea*, *Xanthaphyllum arnottianum, Cullenia exarillata*. For the west coast semi-evergreen forest, the dominant tree species are *Baccaurea courtellansis*, *Hopea parviflora,* and *Xanthaphyllum arnottianum*. In the moist deciduous forest, the dominant tree species are *Terminalia paniculata*, *Aporosa cardiosperma*, and *Olea dioica.* In the *Myristica* swamp forest are *Myristica dactyloides, Myristica fatua,* and *Knema attenuata,* whereas in the tropical hilltop forest, *Vernonia travancorica, Symplocos cochinchinensis,* and *Eleocarpus munronii* were the dominant species.
7. The most dominant families reported are Dipterocarpaceae (FIV=24.92), Clusiaceae (FIV=21.40), and Myrtaceae (FIV=20.78) for the west coast tropical evergreen, the family Euphorbiaceae (FIV=31.68), Dipterocarpaceae (FIV=24.18), and Rubiaceae (FIV=18.99) were the dominant families of the semi-evergreen forest. In the Moist deciduous forest, the most important families are Euphorbiaceae (FIV=52.99), Combretaceae (FIV=41.23), and Malvaceae (31.73), whereas the family Myristicaceae (FIV=149.01), Dipterocarpaceae (FIV=41.08), and Anacardiaceae (FIV=25.86) are dominant. The family Lauraceae (FIV=69.92) and Clusiaceae (FIV=35.71) are dominant in the tropical hilltop forest.
8. The species diversity indices for the forest ecosystems vary significantly with the higher values shown in the west coast tropical evergreen forest. The Shannon-Weiner and Simpson indices were approximately the same for the west coast tropical evergreen and semi-evergreen forests. The Margalef value was reported higher for the evergreen forest.
9. Most of the dominant tree species are well represented in the sapling and seedling stages. The higher density per hectare is reported for the west coast

tropical evergreen forest. The diversity indices vary comparably between the forest types.

10. The soil of all the forest ecosystems is slightly acidic with a moderate amount of soil organic carbon. The soil pH does not show a specific trend with depth. The soil organic carbon and Cation Exchange Capacity are relatively higher on the first horizon and showed decreasing trend across all the forest ecosystems.
11. The soil bulk density was reported low in the first horizon. It showed an increasing trend with depth for all the forest ecosystems. The higher bulk density was recorded for the myristica swamp forest.
12. The electrical conductivity varied significantly with the soil depth levels and among the forest ecosystems. The values showed a decreasing trend with depth in the west coast evergreen and tropical hilltop forest.
13. The land use and land cover change of Shendurney wildlife sanctuary showed significant changes between the period. The major land cover changes were noticed in southern secondary moist deciduous from (4735.13 ha^{1} in 2001 to 3008.82 ha^{-1} in 2018) and west coast tropical semi-evergreen forests (4699.02 ha^{1} in 2001 to 3313.90 ha^{-1} in 2018).
14. The increasing extent of the degraded (2607.97 ha^{1} in 2001 to 4124.51 ha^{-1} in 2018) and open forest (1028.50 ha^{-1} in 2001 to 2306.96 ha^{-1} in 2018) was also reported.
15. The insignificant gain in the west coast tropical evergreen from 3722.02 ha^{-1} in 2001 to 4011.61 ha^{-1} in 2018 and 253.48 ha^{-1} in 2001 to 341.44 ha^{-1} in 2018 for tropical hilltop forest was reported in the land use and land cover analysis of Shendurney wildlife sanctuary.

References

REFERENCE

Abdo, M.T.V., Valeri, S.V., Ferraudo, A.S., Martins, A.L.M. and Spatti, L.R. 2017. Pioneer tree responses to variation of soil attributes in a tropical semi-deciduous forest in Brazil. *J. Sustain. For.* 36(2):134-147.

Abhilash, E.S., Menon, A.R.R., and Balasubramanian, K. 2005. Regeneration status in habitats of *Nageia wallichiana* (Presl.) O. Ktze., Goodrical Reserve Forests, Western Ghats, India. *Indian For.* 135(2):183-200.

Abhilash, E.S. and Menon, A.R.R., 2009. Status survey of Nageia wallichiana (Presl.) O. Ktze. in natural habitats of Goodrical Reserve Forests, Western Ghats, India. *Indian Forester*, *135*(2):281-286.

Abhirami, C. 2020. Ecological status of *Nageia wallichiana* (C.Presl.) Kuntze, an endangered conifer of Western Ghats. MSc. Thesis, Kerala Agricultural University, KAU, 162p.

Adekunle, V. A. J. Adewole, O.O. and Shadrach, O.A. 2016. Tree species diversity and structure of a Nigerian strict nature reserve, *Trop. Ecol.* 53(3):275-289.

Al-Amin, M., Alamgir, M. and Patwary, M.R.A. 2004. Composition and status of undergrowth of a deforested area in Bangladesh. *Asian J. Plant Sci.* 3(5):651-654.

Alexander, E.B. 1980. Bulk densities of California soils in relation to other soil properties. *Soil Sci. Soc. Am. J. 44*(4):689-692.

Amponsah, I. and Meyer, W. 2000. Soil characteristics in teak plantations and natural forests in Ashanti region, Ghana. *Commun. Soil Sci. Plant Anal.* 31(3-4):355-373.

Anbarashan, M. and Parthasarathy, N., 2013. Tree diversity of tropical dry evergreen forests dominated by single or mixed species on the Coromandel coast of India. *Trop. Ecol.*, 54(2):179-190.

Anderson, J.R., 1976. A land use and land cover classification system for use with remote sensor data (Vol. 964). US Government Printing Office.

Anitha, K., Joseph, S., Chandran, R.J., Ramasamy, E.V. and Prasad, S.N. 2010. Tree species diversity and community composition in a human-dominated tropical forest of Western Ghats biodiversity hotspot, India. *Ecol. Complex.*7 (2):217-224.

Anupama, C. & Sivadasan, M. 2004. Mangroves of Kerala, India. *Rheedea* 14: 9–46.

Arisdason, W. and Lakshminarasimhan, P. 2014. Plant Diversity of Kerala State– An Overview. *Central National Herbarium, Botanical Survey of India, Howrah*, 1(4).

Armesto, J.J. and Fuentes, E.R., 1988. Tree species regeneration in a mid-elevation, temperate rain forest in Isla de Chiloé, Chile. *Vegetation* 74(2-3):151-159.

Armesto, J.J., Mitchell, J.D. and Villagran, C., 1986. A comparison of spatial patterns of trees in some tropical and temperate forests, *Biotropic*a, 1(8):11.

Arunachalam, A. 2002. Species diversity in two different forest types of Western Ghats, India. *Ann. For*. 10(2):204-213.

Arvind, B., Swamy, S.L., Sharma, C.M., Sah, V.K. and Singh, R.K. 2010. Phytosociological analysis of overstorey and understory woody perennials along with aspects in Balamdi watershed of mixed dry tropical forest in Chhattisgarh plain. *Indian J. Trop. Biodivers*. 17(1):47-57.

Aweto, A.O. 1981. Secondary succession and soil fertility restoration in south-western Nigeria. *J. Ecol.* 60(2):609-14.

Ayyappan, N. and Parthasarathy, N. 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. *Biodivers. Conserv.* 8(11):1533-1554.

Ayyappan, N. and Parthasarathy, N. 2001. Composition, population structure and distribution of Dipterocarps in a tropical evergreen forest at varagalaiar, anamalais, Western Ghats, South India. *J. Trop. For. Sci.*:311-321.

Balagopalan, M. and Jose, A.I. 1995. Soil chemical characteristics in a natural forest and adjacent exotic plantations in Kerala, India. *J. Trop. For. Sci.* :161-166.

Balagopalan, M. 1995. Soil characteristics in natural forests and *Tectona grandis* and *Anacardium occidentale* plantations in Kerala, India. *J. Trop. For. Sci.*:635-644.

Banerjee, S.K., Singh, S.B., Nath, S. and Pal, D.K. 1985. Some Chemical Properties of Soils under Different Old Stands on Upper Forest Hill of Kalimpong (Darjeeling), West Bengal. *J. Indian Soc. Soil Sci.* 33(4):788-794.

Barkman, J.J., Moravec, J. and Rauschert, S. 1986. Code of Phytosociological Nomenclature. *Vegetation.* 145-195.

Basha, S.C. 1987. Studies on the ecology of evergreen forest of Kerala with special reference to Silent Valley and Attapady. Ph.D. Thesis, University of Kerala, Trivandrum. 232p.

Basha, S.C., Sankar, S. and Balasubramanian, K. 1992. Biodiversity of Silent Valley National Park: a Phytogeographical Analysis. *Indian For. 118*(5):361-366.

Beddome, R.H. (1869-1874). The Flora Sylvatica for Southern India. *Gantz* Brothers, Madras. 3 vols. 205-319p.

Beeck, J.O. 1972. *The phytosociology of the northern-conifer hardwood forests of the central St. Lawrence lowlands of Québec and Ontario* M.sc dissertation, McGill University. 138p.

Behari, B., Agarwal, R., Singh, A.K. and Banerjee, S.K., 2004. Spatial variability of pH and organic carbon in soils under bamboo based agroforestry models in a degraded area. *Indian For. 130*(5):521-529.

Benz, U.C., Hofmann, P., Willhauck, G., Lingenfelder, I. and Heynen, M. 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for

GIS-ready information. *ISPRS J. Photogramm. Remote Sens.* 58(3-4):239-258.

Bharali, S., Paul, A. and Khan, M.L. 2014. Soil nutrient status and its impact on the growth of three rhododendron species in a temperate forest of the eastern himalayas, India. *Taiwan J. For. Sci. 29*(1):33-51.

Bhat, D.M., Naik, M.B., Patagar, S.G., Hegde, G.T., Kanade, Y.G., Hegde, G.N., Shastri, C.M., Shetti, D.M. and Furtado, R.M. 2000. Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Curr. Sci.*: 975-985.

Bhat, P.R. and Kaveriappa, K.M., 2009. Ecological studies on myristica swamp forests of Uttara Kannada, Karnataka, India. *Trop. Ecol. 50*(2):329.

Bhatnagar, H.P. 1965. Soils from different quality sal (*S. robusta*) forests of Uttar Pradesh. *Trop. Ecol. 6:*56-62.

Bhatt, D., Kumar, R., Joshi, G.C. and Tewari, L.M. 2014. Successive variation in phytosociological aspects and threat categorization of Picrorhiza kurroa Royle ex Benth. in Kumaun Himalaya of Uttarakhand. *J. Med. Plants Res.* 8(23):829-833.

Bhatt, R.P. and Bhatt, S. 2016. Floristic composition and change in species diversity over long temporal scales in Upper Bhotekoshi hydropower project area in Nepal. *Am. J. Plant Sci.* 7(01): 28.

Bhuyan, P., Khan, M.L. and Tripathi, R.S. 2003. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. *Biodivers. Conserv.* 12(8):1753-1773.

Bijalwan, A., Swamy, S.L., Sharma, C.M., Sah, V.K. and Singh, R.K. 2009. Phytosociological analysis of overstorey and understorey woody perennials alongwith aspects in balamdi watershed of mixed dry tropical forest in chhattisgarh plain. *Indian J. Trop. Biodiv.* 17(1):47-58.

Binkley, D. and Vitousek, P. 1989. Soil nutrient availability. In *Plant Physiol. Ecol.* pp. 75-96. Springer, Dordrecht.

Braun-Blanquet, J. 1928. *Zur Kenntnis der Vegetationsverhältnisse des Grossen Atlas*. éditeur non identifié, 26p.

Bredenkamp, G., Chytrý, M., Fischer, H.S., Neuhäuslová, Z. and van der Maarel, E. 1998. Vegetation mapping: Theory, methods and case studies: Introduction. *Appl. Veg. Sci.*:162-164.

Black, C. A. 1968. Soil-Plant Relations. 2nd Ed. John Wiley & Sons, Inc., New York-London-Sidney, 3:792p.

Bunyavejchewin, S., 1999. Structure and dynamics in seasonal dry evergreen forest in northeastern Thailand. *J. Vegetation Sci.*, *10*(6):787-792.

Burkill, I.H. 1965. Chapters on the History of Botany in India. Gov. of India Press, p.91.

Champan, J.L. and Reiss, M.J. 1992. Ecology principles and application. Cambridge University Press, Nature - 330pp.

Champion, H.G. and Seth, S.K. 1968. A revised survey of the forest types of India. Govt. *India Publ*. Delhi, 404p.

Chaneton, E.J. and Facelli, J.M., 1991. Disturbance effects on plant community diversity: spatial scales and dominance hierarchies. *Vegetatio*, *93*(2):143-155.

Chapman, J.L. and Reiss, M.J. 1999. *Ecol.: principles appl.*Cambridge University Press. . Cambridge University Press, Nature - 338pp.

Chatterjee, D. 1939. Studies on the endemic flora of India and Burma, *J. Roy. Asiat. Soc.,* Bengal 5:19-57.

Chen, Z.S., Hsieh, C.F., Jiang, F.Y., Hsieh, T.H. and Sun, I.F. 1997. Relations of soil properties to topography and vegetation in a subtropical rain forest in southern Taiwan. *Plant Ecol.* 132(2):229-241.

Chandrashekara, U.M. and Ramakrishnan, P.S. 1994. Vegetation and gap dynamics of a tropical wet evergreen forest in the Western Ghats of Kerala, India. *J. Trop. Ecol.* 10(3):337-354.

Civco, D.L., Hurd, J.D., Wilson, E.H., Song, M. and Zhang, Z. 2002, April. A comparison of land use and land cover change detection methods. In *ASPRS-ACSM Annual Conference* (Vol. 21).12 pp.

Coleman, N.T., Weed, S.B. and McCracken, R.J. 1959. Cation-exchange capacity and exchangeable cations in Piedmont soils of North Carolina. *Soil Sci. Soc. Am. J.* 23(2):146-149.

Comita, L.S., Condit, R. and Hubbell, S.P. 2007. Developmental changes in habitat associations of tropical trees. *J. Ecol. 95*(3):482-492.

Condit, R., 1995. Research in large, long-term tropical forest plots. *Trends Ecol. Evol.* 10(1):18-22.

Condit, R., Sukumar, R., Hubbell, S.P. and Foster, R.B. 1998. Predicting population trends from size distributions: a direct test in a tropical tree community. *Am. Nat.* 152(4):495-509.

Condit, R., Hubbell S.P., LaFrankie J.V., Sukumar, R., Manokaran. N., Foster, R.B. and Ashton, P.S.1996. Speciesarea and species-individual relationships for tropical tree: a comparison of three 50-ha plots. *J. Ecol.* 84: 549–562.

Congalton R. G., and Green, K. 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices boca Rotan. Lewis Publishers, Florida, 348p.

Connell, J.H. 1971. On the role of natural enemies in preventing competitive exclusion in some marine animals and in rain forest trees. *Dynamics of populations*, 298:312p.

Cooke, T. 1901–1908. The flora of the Presidency of Bombay. 2 volumes. Talyor and Francis, London: 1083.

Corrigan, B.M., Kneen, M., Geldenhuys, C.J. and Van Wyk, B.E. 2010. Spatial changes in forest cover on the KwaNibela Peninsula, St Lucia, South Africa, during the period 1937 to 2008. *Southern Forests.* 72(1):47-55.

Curran, L.M., Trigg, S.N., McDonald, A.K., Astiani, D., Hardiono, Y.M., Siregar, P., Caniago, I. and Kasischke, E., 2004. Lowland forest loss in protected areas of Indonesian Borneo. Science, 303(5660):1000-1003.

Curtis, J.T. and Mcintosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31(3):434-455.

Curtis, J.T. and Cottam, G. 1956. Plant ecology workbook, *Laboratory Field Manual*. Burgess Publ. Co., Minnesota. 193 p.

Curtis, J.T., 1959. The vegetation of Wisconsin: an ordination of plant communities. University of Wisconsin Pres. 645 p.

Dai, Z., Liu, Y., Wang, X. and Zhao, D. 1998. Changes in pH, CEC and exchangeable acidity of some forest soils in southern China during the last 32–35 years. *Water, Air, and Soil Pollut.* 108(3-4):377-390.

Damm, C. 2001. *A phytosociological study of Glacier National Park, Montana, USA, with notes on the syntaxonomy of alpine vegetation in western North America* Doctoral dissertation, 242pp.

Daniel, P., Murthy, G.V.S. and Venu, P. 2005. *flora of Kerala*. Botanical Survey of India. Vol 1.53p.

Dar, D.A., Pathak, B. and Fulekar, M.H. 2015. Assessment of soil organic carbon stock of temperate coniferous forests in Northern Kashmir. *Int. J. Environ.* 4(1):161-178.

Dash, A.K., Upadhyay, V.P. and Patra, H.K., 2020. Floristic assessment of semi evergreen forests of a peripheral site in Hadagarh Sanctuary, Odisha, India. *Biodivers. Conserv.*, *12*(2):104-112.

Davis, G.W. and Richardson, D.M. (eds.) (1995) Held, A., Byrne, G., Anstee, J., Williams, N. & Field, C.B. Mediterranean-type ecosystems: the function of biodiversity, Springer, Berlin, 1995. XVIII, 366p.

Deb, P. and Sundriyal, R.C., 2008. Tree regeneration and seedling survival patterns in old-growth lowland tropical rainforest in Namdapha National Park, north-east India. *Forest Ecol. Manag.*, *255*(12):3995-4006.

Deka, J., Tripathi, O.P. and Khan, M.L. 2012. High dominance of *Shorea robusta* Gaertn. in alluvial plain Kamrup sal forest of Assam, NE India. *Int. J. Ecosyst. 2*(4):67-73.

Deepa, M.R., Udayan, P.S. and Anilkumar, K.A. 2017. Taxonomical and phytosociological studies on Chithalikavu-A sacred grove, Thrissur district, Kerala. *Trop. Plant Res. 4:*20-30.

Denslow, J.S., 1995. Disturbance and diversity in tropical rain forests: the density effect. *Ecol. Appl.* 5(4):962-968.

Devi, L.S. and Yadava, P.S. 2006. Floristic diversity assessment and vegetation analysis of tropical semi-evergreen forest of Manipur, north east India. *Trop. Ecol.* 47(1):89-98.

Devi, U. and Behera, N. 2003. Assessment of plant diversity in response to forest degradation in a tropical dry deciduous forest of Eastern Ghats in Orissa. *J. Trop. For. Sci.* pp.147-163.

Dhaulkhandi, M., Dobhal, A., Bhatt, S. and Kumar, M. 2008. Community structure and regeneration potential of natural forest site in Gangotri, India. *J. Basic Appl.* Sci. 4(1):49-52.

Digvijay, R., Gopal, R., Kumar, Y. and Ramola, G.C. 2020. Soil Chemical Properties of *Cedrus deodara* (Roxb) G. Don. Forest Soil in Garhwal Himalaya, India. 39(1):42-51.

Divya, V., Padmalal, D and Mohannan, C.N. 2016. Soil of Southern Western Ghats (India) - a potential archive of late Holocene Climate Records. *Int. J. Sci. Res. Pub*. 6(3): 22-26.

Dutta, G. and Devi, A. 2013. Plant diversity and community structure in tropical moist deciduous sal (*Shorea robusta* Gaertn.) forest of Assam, northeast India. *J. ISSN, 2319*: 8745.

Ellenberg, D. and Mueller-Dombois, D. 1974. *Aims and methods of vegetation ecology*. New York: Wiley, p547.

Elouard, C., Pascal, J.P., Pelissier, R., Ramesh, B.R., Houllier, F., Durand, M., Aravajy, S., Moravie, M.A. and Gimaret-Carpentier, C. 1997. Monitoring the structure and dynamics of a dense moist evergreen forest in the Western Ghats (Kodagu District, Karnataka, India), *Trop. Ecol.* 38(2):193-214.

Eni, D.D., Iwara, A.I. and Offiong, R.A. 2012. Analysis of soil-vegetation interrelationships in a south-southern secondary forest of Nigeria. *Int. J. For. Res.* 2012:1-8.

Evrendilek, F., Celik, I. and Kilic, S. 2004. Changes in soil organic carbon and other physical soil properties along adjacent Mediterranean forest, grassland, and cropland ecosystems in Turkey. *J. Arid Environ.* 59(4):743-752.

Ewers, R.M., Didham, R.K. 2006. Confounding factors in the detection of species responses to habitat fragmentation. *Biol. Rev*. 81:117–142.

FAO 2001. Global forest resources assessment 2000: main report. FAO forestry paper 140, Food and Agriculture Organization, Rome, Italy.

Farooquee, N.A. and Saxena, K.G. (1996). Conservation and utilization of medicinal plants in high hills of central Himalayas. *Environ. Conserv*. 23:75-80.

Fischer, C. E. C. 1921. A survey of the flora of the Anamalai Hills in the Coimbatore District, Madras Presidency. Records of Botanical survey of India 9(1):1–218.

Fjeldså, J. 1994. Geographical patterns for relict and young species of birds in Africa and South America and implications for conservation priorities. *Biodivers. Conserv.* 3(3):207-226.

Fonge, B.A., Yinda, G.S., Focho, D.A., Fongod, A.G.N. and Bussmann, R.W. 2005. Vegetation and soil status on an 80 year old lava flow of Mt. Cameroon, West Africa. *Lyonia.*8 (1):17-39.

Forman, R.T. and Hahn, D.C., 1980. Spatial patterns of trees in a Caribbean semievergreen forest. *Ecology*, *61*(6):1267-1274.

Foster, D.R. 1984. Phytosociological description of the forest vegetation of southeastern Labrador. *Can. J. Bot. 62*(5):899-906.

Fox, J.E.D. 1967. An enumeration of lowland dipterocarp forest in Sabah. *Malaysian For.* 30:263-279.

Fredericksen, T.S. 1999. Regeneration status of important tropical forest tree species in Bolivia: assessment and recommendations. *For. Ecol. Manag.* 124(2-3):263-273.

Fyson, P.F. 1932. The flora of the South Indian hill stations. 2 Vols. Madaras, p611.

Gadgil, M.A.D.H.A.V. and Meher-Homji, V.M. 1986, November. Localities of great significance to conservation of India's biological diversity. In *Proceedings of the Indian Academy of Sciences (Animal Sciences/Plant Sciences Supplement) November* Vol. 180, p. 165.

Gairola, S., Sharma, C.M., Ghildiyal, S.K. and Suyal, S. 2012. Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. *The Environmentalist.* 32(4):512-523.

Gamble, J.S. and Fischer, C.E.C. 1915- 1936. Flora of the Presidency Madras. Vols. 1-3. Adlard & Co. London (Reprinted 1957). Botanical Survey of India, Calcutta, pp134-145.

Ganesh, T., Ganesan, R., Devy, M.S., Davidar, P. and Bawa, K.S. 1996. Assessment of plant biodiversity at a mid-elevation evergreen forest of

Kalakad–Mundanthurai Tiger Reserve, Western Ghats, India. *Curr. Sci.*:379-392.

Gautam, M.K., Manhas, R.K. and Tripathi, A.K. 2014. Plant species diversity in unmanaged moist deciduous forest of Northern India. *Curr. Sci.*:277-287.

Gianguzzi, L., Papini, F. and Cusimano, D. 2016. Phytosociological survey vegetation map of Sicily (Mediterranean region). *J. Maps.* 12(5):845-851.

Giliba, R.A., Boon, E.K., Kayombo, C.J., Musamba, E.B., Kashindye, A.M. and Shayo, P.F. 2011. Species composition, richness and diversity in Miombo woodland of Bereku Forest Reserve, Tanzania. *J. Biodivers. 2*(1):1-7.

Giriraj, A., Murthy, M.S.R. and Ramesh, B.R. 2008. Vegetation composition, structure and patterns of diversity: a case study from the tropical wet evergreen forests of the Western Ghats, India. *Edinburgh J. Bot. 65*(3):447.

Givnish, T.J. 1999. On the causes of gradients in tropical tree diversity. *J. Ecol.* 87(2):193-210.

Gliessman, R. S., 2000. Field and laboratory Investigations in Agro Ecology. New York: (Eric W. Engles, ed.) Lewis Publishers.

Godefroid, S. and Koedam, N. 2003. Distribution pattern of the flora in a peri-urban forest: An effect of the city–forest ecotone. *Landsc. Urban Plan.* 65: 169–185.

Goff, F.G. and West, D., 1975. Canopy-understory interaction effects on forest population structure. *For. Sci.,* 21(2):98-108.

Gosain, B.G. 2016. An Assessment of C-stock and Soil physicochemical properties in standing dead trees of Pine (*Pinus roxburghii* Sargent) forests in a Mountain Watershed Kumaun Himalaya, India. *Int. J. Multidisciplinary Res. Dev. 3*(4):279-286.

Gosain, B.G., Negi, G.C.S., Dhyani, P.P., Bargali, S.S. and Saxena, R. 2015. Ecosystem services of forests: Carbon Stock in vegetation and soil components in a watershed of Kumaun Himalaya, India. *Int. J. Ecol. Environ. Sci. 41*(3-4):177-188.

Guo, X., Meng, M., Zhang, J. and Chen, H.Y. 2016. Vegetation change impacts on soil organic carbon chemical composition in subtropical forests. *Sci. Rep.* 6:29607.

Hadi, S., Ziegler, T., Waltert, M. and Hodges, J.K. 2009. Tree diversity and forest structure in northern Siberut, Mentawai islands, Indonesia. *Trop Ecol.,* 50(2):315-327.

Hailu, H. 2017. Analysis of vegetation phytosociological characteristics and soil physico-chemical conditions in Harishin rangelands of eastern Ethiopia. *Land*, 6(1):4.

Halle, F., Oldeman, R.A. and Tomlinson, P.B. 2012. *Tropical trees and forests: an architectural* Anal.. Springer Science & Business Media, Verlag, Berlin, Germany, Springer. 441 pp.

Handayani, I.P., Prawiton, P., and Ihsan, M. 2012. Soil changes associated with *Imperata cylindrica* grassland conversion in Indonesia. *Int. J. Soil Sci. 7*(2), 61p.

Haritha, M. and Nandu, V.S. 2016. Inventory of Endemic and Threatened Flora of Three Sacred Groves in Kannur District, Northern Kerala, India. *Bio. Sci. Res. Bull. 32*(1 and 2):21-37.

Hartshorn, G.S. 1980. Neotropical forest dynamics. *Biotropica.* 12: 23-30.

Hasmadi, M.I., Zaki, M.H., Adnan, I.A., Pakhriazad, H.Z. and Fadlli, M.A. 2010. Determining and mapping of vegetation using GIS and phytosociological approach in Mount Tahan, Malaysia. *J. Agric. Sci. 2*(2):80.

Hayek, L.C. and Buzas, M.A., 1997. Surveying natural populations, Columbia University Press New York, p448.

Helling, C.S., Chesters, G. and Corey, R.B. 1964. Contribution of organic matter and clay to soil cation-exchange capacity as affected by the pH of the saturating solution. *Soil Sci. Soc. Am. J.*, *28*(4):517-520.

Hendershot, W.H. and Duquette, M. 1986. A simple barium chloride method for determining cation exchange capacity and exchangeable cations. *Soil Sci. Soc. America J.* 50: 605-608.

Henry, A.N., Kumari, G.R. and Chitra V. 1987. Flora of Tamil Nadu, India, Ser.1, Vol. 2. Botanical Survey of India, Coimbatore, pp 186.

Henry, A.N., Chitra, V. and Balakrishnan, N.P. 1989. Flora of Tamil nadu, India, Ser 1. Vol. 3. Botanical Survey of India, Coimbatore.

Hernandez, L., Dezzeo, N., Sanoja, E., Salazar, L. and Castellanos, H. 2012. Changes in structure and composition of evergreen forests on an altitudinal gradient in the Venezuelan Guayana Shield. *Revista de Biología Trop.* 60(1):11-33.

Hewetson, C.E., 1956. A discussion on the" climax" concept in relation to the tropical rain and deciduous forest. *Empire Forestry Review*, pp274-291.

Heywood, V.H. and Watson, R.T. 1997. Global biodiversity assessment. *Identification of Wild Food and Non-Food Plants of the Mediterranean Region*, pp.7-9.

Ho, C.C., McC, D. and Poore, M.E.D. 1987. Forest composition and inferred dynamics in Jengka Forest Reserve, Malaysia. *J. Trop. Ecol.*:25-56.

Hobbs, R.J., Richardson, D.M. and Davis, G.W. 1995. Mediterranean-type ecosystems: opportunities and constraints for studying the function of biodiversity. In *Mediterranean-type ecosystems*, Springer, Berlin, Heidelberg, 1-42.

Honey B. 2020. Zonation of woody vegetation and soil along altitude gradient in Mankulam Division, Kerala. MSc. Thesis submitted to Department of Natural resource Management, Kerala Agricultural University, KAU, 128p.

Hong, W., Jiang, R., Yang, C., Zhang, F., Su, M. and Liao, Q. 2016. Establishing an ecological vulnerability assessment indicator system for spatial recognition and management of ecologically vulnerable areas in highly urbanized regions: A case study of Shenzhen, China. *Ecological indicators*, 69:540-547.

Hooker, J.D. and Thomson, T. 1855. Flora indica, vol. 1. *W. Pamplin, London,* 285p.

Hooker, W.J., 1906. *Curtis's botanical magazine* (Vol. 1). Academic Press.

Hooker, J.D. (Ed.) 1872-1897. Flora of British India. Vol. I-VII. W. Clowes & Co. London p 1-7.

Hooker, J.D., 1907. Sketch of the Flora of British India. *Imperial Gazetter of India*. 1: 157-212.

Hubbell, S.P. 1979. Tree dispersion, abundance, and diversity in a tropical dry forest. *Science*, *203*(4387):1299-1309.

Ilorkar, V.M. and Khatri, P.K. 2003. Phytosociological study of navegaon national park (Maharashtra). *Indian For.*, 129(3):377-387.

Ilorker, V.M. and Toley, N.G., 2001. Floristic diversity and soil studies in Navegaon National Park (Maharashtra). *Indian J. For.*, *24*(4):442-447.

Inuwa, A. and Bilyaminu, H. 2020. Diversity of Regenerating Tree Species in Response to Different Soil Chemical Properties in Parkland Area of Gwarzo Local Government, Kano State, *The Bioscan*, 15(4):505-509.

Jaccard, P. 1912. The distribution of the flora in the alpine zone. 1. *New Phyto*. 11(2):37-50.

Jarman, S.J., Kantvilas, G. and Brown, M.J. 1991. *Floristic and ecological studies in Tasmanian rainforest*. Tasmanian component of the National Rainforest Conservation Program, p.47-51.

Jalabert, S.S.M., Martin, M.P., Renaud, J.P., Boulonne, L., Jolivet, C., Montanarella, L. and Arrouays, D. 2010. Estimating forest soil bulk density using boosted regression modelling. *Soil Use Manag. 26*(4):516-528.

Jayakumar, R. and Nair, K.K.N. 2013. Species diversity and tree regeneration patterns in tropical forests of the Western Ghats, India, *ISRN Ecol.*, 14p.

Jayakumar, S., Kim, S.S. and Heo, J. 2011. Floristic inventory and diversity assessment-a critical review. *Proceedings of the Intl. Acad. Ecol. and Environ. Sci.*, 1(3-4), 151p.

Jayapal, J., Tangavelou, A.C. and Panneerselvam, A. 2014. Studies on the plant diversity of Muniandavar sacred groves of Thiruvaiyaru, Thanjavur, Tamil Nadu, India. *Hygeia JD Med*, 6(1):48-62.

Jayanthi, P. and Rajendran, A. 2013. Life-forms of Madukkarai hills of Southern Western Ghats, Tamil Nadu, India, *Life Sci. Leafl.* 43:57-61p.

Jehangir, A., Yousuf, A.R., Reshi, Z.A., Tanveer, A. and Ahmad, A. 2012. Comparison of physical, chemical and microbial properties of soils in a clear-cut and adjacent intact forest in North Western Himalaya, India. *Int. J. Soil Sci. 7*(3):71.

Jensen, J.R., 2004. "Digital Change Detection" Introductory digital image processing: a remote sensing perspective. Prentice-Hall, New Jersey, 314p.

Jina, B.S., Bohra, C.S., Lodhiyal, L.S. and Sah, P. 2011. Soil characteristics in oak and pine forests of Indian Central Himalaya. *E-Int. Sci. Res. J. 3*(1):19-22.

Jobbágy, E.G. and Jackson, R.B., 2000. The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological applications*, *10*(2):423-436.

Johnston, A.E. 1986. Soil organic matter, effects on soils and crops. *Soil use Manag. 2*(3):97-105.

Johnston, M. and Gillman, M. 1995. Tree population studies in low-diversity forests, Guyana. I. Floristic composition and stand structure. *Biodivers. Conserv. 4*(4):339-362.

John, R., Dalling, J.W., Harms, K.E., Yavitt, J.B., Stallard, R.F., Mirabello, M., Hubbell, S.P., Valencia, R., Navarrete, H., Vallejo, M. and Foster, R.B. 2007. Soil nutrients influence spatial distributions of tropical tree species. *Proceedings of the National Academy of Sciences*, 104(3):864-869.

Jones, C.G., Lawton, J.H. and Shachak, M., 1994. Organisms as ecosystem engineers. In *Ecosystem management*, Springer, New York, 130-147p.

Jose, S., Sreepathy, A., Kumar, B.M. and Venugopal, V.K. 1994. Structural, floristic and edaphic attributes of the grassland-shola forests of Eravikulam in peninsular India. *For. Ecol. Manag.* 65(2-3):279-291.

Joshi, P.C., Pandey, P. and Kaushal, B.R. 2013. Analysis of some Physico-chemical parameters of soil from a protected forest in Uttarakhand. *Nat. Sci. 11*(1):136-140.

Kacholi, D.S., 2014. Analysis of structure and diversity of the kilengwe forest in the Morogoro Region. *Tanzania Intl. J. Biodiver.*, 2014:1-8.

Kadavul, K. and Parthasarathy, N. 1999. Plant biodiversity and conservation of tropical semi-evergreen forest in the Shervarayan hills of Eastern Ghats, India. *Biodivers. & Conserv. 8*(3):419-437.

Kanade, R., Tadwalkar, M., Kushalappa, C. and Patwardhan, A. 2008. Vegetation composition and woody species diversity at Chandoli National Park, northern Western Ghats, India. *Curr. Sci.* 637-646.

Kandi, B., Sahu, S.C., Dhal, N.K. and Mohanty, R.C. 2011. Species diversity of vascular plants of Sunabeda wildlife sanctuary, Odisha, India. *New York Sci. J. 4:*1-9.

Kaushal, R., Bhandari, A.R., Sharma, J.C. and Tripathi, D. 1997. Soil fertility status under natural deodar (*Cedrus deodara*) forest ecosystem of north-west Himalayas. *Indian J. For. 20*(2):105-111.

Keel, S.H.K. and Prance, G.T. 1979. Studies of the vegetation of a white-sand black-water igapó (Rio Negro, Brazil). *Acta Amaz.*645-655.

Keel, S., Gentry, A.H. and Spinzi, L. 1993. Using vegetation analysis to facilitate the selection of conservation sites in eastern Paraguay, *Conserv. Bio. 7*(1):66-75.

KDF [Kerala Forest Department] 2014. Management Plan of Shendurney Wildlife Sanctuary 2013-2014 to 2020-2021 http://www.forest.kerala .gov.in/index.php/forest/forest-management/management-plans Accessed on 23-02-2021.

Khera, N., Kumar, A., Ram, J. and Tewari, A. 2001. Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India. *Trop. Ecol. 42*(1):83-95.

Khumbongmayum, A. D., M. L. Khan and R. S. Tripathi. 2005. Survival and growth of seedlings of a few tree species in the four sacred groves of Manipur, Northeast India. *Curr. Sci.* 88: 1781-1788.

Kigomo, B.N., Savill, P.S. and Woodell, S.R., 1990. Forest composition and its regeneration dynamics; a case study of semi-deciduous tropical forests in Kenya, *Afr. J. Ecol*., 28(3):174-188.

Kim, M., Madden, M. and Warner, T.A. 2009. Forest type mapping using object-specific texture measures from multispectral Ikonos imagery. *Photogramm. Eng. Remote Sensing*, 75(7):819-829.

Kim, C., 2016. Land use classification and land use change analysis using satellite images in Lombok Island, Indonesia. *For. Sci. Technol.*, *12*(4):183-191.

Kindt, R. and Coe, R. 2005. Tree Diversity Analysis. *A Manual and Software for Common Statistical Methods for Ecological and Biodiversity Studies*. Nairobi: World Agrofrestry Centre (ICRAF), 196p.

Knight, D.H. 1975. A phytosociological analysis of species-rich tropical forest on Barro Colorado Island, Panama. *Ecol. Monogr. 45*(3):259-284.

Krishnan, R.M. and Davidar, P. 1996. The shrubs of the Western Ghats (South India): floristic and status. *J. Biogeogr.* 23(6):783-789.

Krishnamurthy, Y.L., Prakasha, H.M., Nanda, A., Krishnappa, M., Dattaraja, H.S. and Suresh, H.S. 2010. Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India. *Trop. Ecol. 51*(2):235.

Kumar, M., Sharma, C.M. and Rajwar, G.S. 2004. Physico-chemical properties of forest soil along altitudinal gradient in Garhwal Himalaya. *J. Hill Res.* 17(2):60-64.

Kumar, M. and Bhatt, V.P. 2006. Plant biodiversity and conservation of forests in foot hills of Garhwal Himalaya. *J. Ecol. Appl.* 11(2):43-59.

Kumar, J.N., Kumar, R.N., Bhoi, R.K. and Sajish, P.R. 2010a. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. *Trop. Ecol. 51*(2):273-279.

Kumar, J.N., Patel, K., Kumar, R.N. and Bhoi, R., 2010b. An assessment of carbon stock for various land use system in Aravally mountains, Western India. *Mitigation and adaptation strategies for global change*, 15(8):811-824.

Kumar, J.N., Patel, K., Kumar, R.N. and Kumar, R.B. 2011. Forest structure, diversity and soil properties in a dry tropical forest in Rajasthan, Western India. *Ann. For. Res. 54*(1):89-98.

Kumar, V. and Desai, B.S. 2016a. Biodiversity and phytosociological analysis of plants around the Chikhali Taluka, Navsari district, Gujarat, India. *Ecoscan,* 10: 689-696.

Kumar, V. and Desai, B.S. 2016b. Phytosociological study of Waghai forest range in Dang district, south Gujarat, India. *Environment and Bio-sciences*, *30*(02):549-553.

Kumar, S., 2019. Phytosociological study of Keshkal Valley, Kondagaon district in Chhattisgarh, *Life sci. Leafl.* 113*:*33-42.

Kumar, S.S. and Kumar, B.M. 1997. Floristics, biomass production and edaphic attributes of the mangrove forests of puduvyppu, Kerala, *Ind. J. For.* 20(2):136-143.

Kumar, V. and Desai, B.S. 2016. Biodiversity and phytosociological analysis of plants around the Chikhali Taluka, Navsari district, Gujarat, India. *Ecoscan,* 10*:*689-696.

Kushwaha, S.P.S. and Madhavan Unni, N.V., 1989. Hybrid interpretation for tropical forest classification. *Asian-Pacific Remote Sensing J.* 1(2):69-75.

Kushwaha, S.P.S., 1990. Forest-type mapping and change detection from satellite imagery. *J. Photogramm. Remote Sens. ISPRS J*, *45*(3):175-181.

Kushwaha, S.P.S. and Nandy, S. 2012. Species diversity and community structure in sal (*Shorea robusta*) forests of two different rainfall regimes in West Bengal, India. *Biodivers. Conserv.*, 21(5):1215-1228.

Kyereh, B., Swaine, M.D. and Thompson, J., 1999. Effect of light on the germination of forest trees in Ghana. *J. Ecol.*, *87*(5):772-783.

Lal, J.B 1989. India's forests, Myths and reality. Natraj Publishers, Dehra dun, India. Pp. 89-97.

Latham, P.A., Zuuring, H.R. and Coble, D.W. 1998. A method for quantifying vertical forest structure. *For. Ecol. Manag.* 104(1-3):157-170.

Lemos, M.C., Pellens, R. and Lemos, L.C.D. 2001. Profile diagrams and floristic in two areas of a coastal forest in the Municipality of Maricá-RJ. *Acta Bot. Bras.* 15(3):321-334.

Lepping, O. and Daniel, F.J., 2007. Phytosociology of beach and salt marsh vegetation in Northern West Greenland. *Polarforschung*, 76(3):95-108.

Leprieur, C., Kerr, Y.H., Mastorchio, S. and Meunier, J.C. 2000. Monitoring vegetation cover across semi-arid regions: comparison of remote observations from various scales. *Int. J. Remote Sens*. 21(2):281-300.

Leskiw, L.A. 1998. Land capability classification for forest ecosystems in the oil sands region: Working manual. Alberta Environmental Protection. Environmental Regulatory Service, Land Reclamation Division, Edmonton, Alberta, Canada, 30(18):93.

Lieberman, D., Lieberman, M., Peralta, R. and Hartshorn, G.S., 1996. Tropical forest structure and composition on a large-scale altitudinal gradient in Costa Rica. *J. Ecol.*:137-152.

Likens, G.E., Bormann, F.H., Pierce, R.S. and Reiners, W.A. 1978. Recovery of a deforested ecosystem. *Science*, 199(4328):492-496.

Lima, A.L.A., Sampaio, E.V.D.S.B., de Castro, C.C., Rodal, M.J.N., Antonino, A.C.D. and de Melo, A.L. 2012. Do the phenology and functional stem attributes of woody species allow for the identification of functional groups in the semiarid region of Brazil? *Trees*, 26(5):1605-1616.

Lira, P.K., Tambosi, L.R., Ewers, R.M. and Metzger, J.P., 2012. Land-use and land-cover change in Atlantic Forest landscapes. *For. Ecol. Manag*., 278:80-89.

Liu, Z., Zhu, Y., Wang, J., Ma, W. and Meng, J., 2019. Species association of the dominant tree species in an old-growth forest and implications for enrichment planting for the restoration of natural degraded forest in subtropical China. *Forests*, *10*(11):957.

Lorimer, C.G., Dahir, S.E. and Nordheim, E.V., 2001. Tree mortality rates and longevity in mature and old-growth hemlock-hardwood forests. *J. Ecol.,* 89(6):960-971.

Looman, J. 1979. On pattern in vegetation. *Phytocoenologia* 6: 37-48.

Losos, E.C. and E. G. Leigh, Jr. 2004. (eds.). Tropical Forest Diversity and Dynamism. The University of Chicago Press, Chicago and London, pp 506–516.

Lovejoy, T.E. 1980. Changes in biological diversity. In: Barney, G.O. (Ed.), the Global 2000 Report to the President, Vol. 2 (The Technical Report). Penguin Books, Har-mondsworth, pp. 327-332.

Ludwig, J.A., Quartet, L., Reynolds, J.F. and Reynolds, J.F. 1988. Statistical ecology: a primer in methods and computing (Vol. 1). John Wiley & Sons, 339p.

MacMahon, J.A. and Schimpf, D.J., 1981. Water as a factor in the biology of North American desert plants. US IBP synthesis series. Stroudsburg: Hutchinson and Ross, 30:114-171p.

Mackinnon, J. and K. Mackinnon. 1986. Review of the protected areas system in the IndoMalayan Region. IUCN, Gland. 284 p.

Magurran, A.E. 1988. *Ecological diversity and its measurement*. Princeton University Press. Jersey, 179p.

Magurran, A.E., 1998. Population differentiation without speciation. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *353*(1366):275-286.

Maguran, A.E., 2004. Measuring biological diversity assessment.Blackwell Publishing,248p.

Magurran, A.E. 2005. Biological diversity. *Current Biology*, *15*(4):116-118p.

Mahapatra, A.K., Acharya, P.K. and Debata, A.K. 2013. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *Int. J. Biodivers. Conserv.* 5(10):625-639.

Malik, Z.A. and Bhatt, A.B. 2016. Regeneration status of tree species and survival of their seedlings in Kedarnath Wildlife Sanctuary and its adjoining areas in Western Himalaya, India. *Trop. Ecol.* 57(4):677-690.

Mallupattu, P.K. and Sreenivasula Reddy, J.R., 2013. Analysis of land use/land cover changes using remote sensing data and GIS at an Urban Area, Tirupati, India. *Sci. World J.*, 2013:6.

Mandal, A.K., Nath, S., Gupta, S.K. and Banerjee, S.K. 1990. Characteristics and nutritional status of soils of Middle Hill and Upper Hill Forest of the eastern Himalayas. *J. Indian Soc. Soil Sci. 38*(1):100-106.

Mani, M.S. 1974. Biogeographical evolution in India. In *Ecology and biogeography in India*, Springer, Dordrecht, pp. 698-724.

Manilal, K.S. 1988. Flora of Silent Valley tropical rain forests of India. *Flora of Silent Valley tropical rain forests of India,* 398p.

Maro, R.S., Chamshama, S.A.O., Nsolomo, V.R. and Maliondo, S.M. 1993. Soil chemical characteristics in a natural forest and a *Cupressus Lusitanica* plantation at West Kilimanjaro, Northern Tanzania. *J. Trop. For. Sci.*:465-472.

Matschonat, G. and Vogt, R. 1997. Effects of changes in pH, ionic strength, and sulphate concentration on the CEC of temperate acid forest soils. *Eur. J. Soil Sci.* 48(1):163-171.

Matthew, K.M. 1983. The Flora of the Tamil Nadu Carnatic. The Rapinat Herbarium, vol. 3. St. Josephs College, Tiruchirapalli, India, IXXXIV (2154).

Menon, A.R.R. and Balasubramanyan, K. 1985. *Species relation studies in moist deciduous forests of Trichur Forest Division (Kerala)*. Division of Ecology, Kerala Forest Research Institute, KFRI *Res. Rep. No.33*: 200p.

Menon, A.R.R. and Sasidharan, N. 2005. Biodiversity characterization at landscape level using remote sensing and GIS in Kerala. *Res. Rep. No.* 274:222p.

Miles, J. 1985. The pedogenic effects of different species and vegetation types and the implications of succession. *J. Soil. Sci.*, *36*(4):571-584.

Miller, A.B., Bryant, E.S. and Birnie, R.W. 1998. An analysis of land cover changes in the Northern Forest of New England using multitemporal Landsat MSS data. *Int. J. Remote Sens. 19*(2):245-265.

Misra, R. 1968. *Ecology workbook*. Oxford and IBH Publishing C., New Delhi, India. Pp. 244-245.

Mishra, B.P., Tripathi, O.P. and Laloo, R.C., 2005. Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. *Trop. Ecol.*, *46*(2):241-252.

Mishra, R.K., Upadhyay, V.P., Nayak, P.K., Pattanaik, S. and Mohanty, R.C. 2012. Composition and Stand Structure of Tropical Moist Deciduous Forest of Similipal Biosphere Reserve, Orissa, India. *Forest ecosystems–more than just trees*, 109p.

Mishra, A.K., Bajpai, O., Sahu, N., Kumar, A., Behera, S.K., Mishra, R.M. and Chaudhary, L.B. 2013. Study of plant regeneration potential in tropical moist deciduous forest in northern India. *Int. J. Environ. 2*(1):153-163.

Mishra, G., Das, P.K., Borah, R. and Dutta, A. 2017. Investigation of phytosociological parameters and physico-chemical properties of soil in tropical semi-evergreen forests of Eastern Himalaya. *J. For. Res. 28*(3):513-520.

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M. and Gascon, C. 2011. Global biodiversity conservation: the critical role of hotspots. In *Biodiversity hotspots* (pp. 3-22). Springer, Berlin, Heidelberg.

Mohandass, D. and Davidar, P. 2009. Floristic structure and diversity of a tropical montane evergreen forest (shola) of the Nilgiri Mountains, southern India. *Trop. Ecol. 50*(2):219.

Mohanan, M. and Daniel, P. 2005. Introduction. In: The Flora of Kerala. Volume 1. Ranunculaceae – Connaraceae. Botanical Survey of India, Kolkata. pp. 1–110.

Morris, E.K., Caruso, T., Buscot, F., Fischer, M., Hancock, C., Maier, T.S., Meiners, T., Müller, C., Obermaier, E., Prati, D. and Socher, S.A., 2014. Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. *Ecol. Evol.*, *4*(18):3514-3524.

Mueller-Domboise D., Ellenberg H. 1974. *Aims and methods of vegetation ecology*. Wiley, New York, 547p.

Murali, K.S., Shankar, U., Shaanker, R.U., Ganeshaiah, K.N. and Bawa, K.S. 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic botany*, 50(3):252-269.

Murthy, I.K., Murali, K.S., Hegde, G.T., Bhat, P.R. and Ravindranath, N.H. 2002. A comparative analysis of regeneration in natural forest and joint forest management plantations in Uttara Kannada Dist., Western Ghats. *Curr. Sci*. 83:1358-1364.

Murthy, G.V.S. and Veṇu, P. 2005. *The Flora of Kerala: Ranunculaceae-Connaraceae* (Vol. 1). Botanical Survey of India pp. 1–110.

Murthy, I.K., Bhat, S., Sathyanarayan, V., Patgar, S., Beerappa, M., Bhat, P.R., Bhat, D.M., Ravindranath, N.H., Khalid, M.A., Prashant, M. and Iyer, S. 2016. Vegetation structure and composition of tropical evergreen and deciduous forests in Uttara Kannada District, Western Ghats under different disturbance regimes. *Trop. Ecol. 57*(1):77-88.

Muthuramkumar, S., Ayyappan, N., Parthasarathy, N., Mudappa, D., Raman, T.S., Selwyn, M.A. and Pragasan, L.A. 2006. Plant community structure in tropical rain forest fragments of the Western Ghats, India 1. *Biotropica: J. Biol. Conserv. 38*(2):143-160.

Myers, N. 1988. Threatened biotas:" hot spots" in tropical forests. *Environmentalist*, *8*(3):187-208.

Myers, N. 1990. The biodiversity challenge: expanded hot-spots analysis. *Environmentalist*, 10(4):243-256.

Myers, N. 1993. Questions of mass extinction. *Biodivers. Conserv. 2*(1):2-17.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature. 403*(6772):853-858.

Myo, K.K., Thwin, S. and Khaing, N. 2016. Floristic composition, structure and soil properties of mixed deciduous forest and deciduous dipterocarp forest: Case study in Madan Watershed, Myanmar. *Am. J. Plant Sci. 7*(02):279.

Naidu, M.T. and Kumar, O.A., 2015. Tree species diversity in the Eastern Ghats of northern Andhra Pradesh, India. *Journal of Threatened Taxa*, *7*(8):7443-7459.

Naidu, M.T. and Kumar, O.A. 2016. Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. *J. Asia-Pacific Biodivers. 9*(3):328-334.

Nair, N.C. and Henry, A.N. 1983. Flora of Tamil Nadu, India. Ser.1. Vol.1. Botanical Survey of India, Coimbatore.

Nair, N. and Daniel, P. 1986. The floristic diversity of the Western Ghats and its conservation: a review. *Proc. Indian Acad. Sci. (Animal Sci./Plant Sci.) Suppl.*:127-163.

Nair, K. N. and A. R. Menon. 2000. Evaluation of the population regeneration and invasion status of selected tree endemics in the shola forests of Kerala. KFRI Research Report 192. Kerala Forest Research Institute, Peechi, Thrissur, 70p.

Nakashizuka, T., Yusop, Z. and Nik, A.R. 1992. Altitudinal zonation of forest communities in Selangor, Peninsular Malaysia. *J. Trop. For. Sci.*:233-244.

Nath, P.C., Arunachalam, A., Khan, M.L., Arunachalam, K. and Barbhuiya, A.R. 2005. Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, northeast India. *Biodivers. Conserv.* 14(9):2109-2135.

Nayar, M.P. 1977. Changing patterns of Indian flora. Bulletin Botanical Survey of India 19: 145–154.

Nayar, M.P. 1996. *Hot spots of endemic plants of India, Nepal and Bhutan*. Tropical Botanic garden and research Institute, *Botany*, 252p.

Nayar, M.P. 1997. Biodiversity challenges in Kerala and science of conservation biology. *Biodiversity of Tropical Forests the Kerala Scenario, STEC, Kerala, Trivandrum*, pp.7-80.

Nayar, T.S. 2006. *Flowering plants of Kerala*. Tropical Botanic Garden and Research Institute, 1069p.

Nayar, T.S., Sibi, M., Rasiya, A.B., Mohanan, N. and Rajkumar, G., 2008. Flowering plants of Kerala: status and statistics. *Rheedea*, *18*(2):95-106.

Negi, V.S., Giri, L. and Sekar, K.C. 2018. Floristic diversity, community composition and structure in Nanda Devi National Park after prohibition of human activities, Western Himalaya, India. *Curr. Sci.* 115(6):1056.

Ndah, N.R., Andrew, E.E. and Bechem, E. 2013. Species composition, diversity and distribution in a disturbed Takamanda Rainforest, South West, Cameroon. *Afr. J. Plant Sci.* *7*(12):577-585.

Nosrati, H., Mirtajeddini, S., Jahanshahi, M., and Haghighi, A. R. 2017. Phytosociologial study of rabor region, Kerman, Iran. *Agric. For*. 63 (2):49-58.

Odum, E.P.1971. *Fundamentals of ecology*. W.B. Saunders Co., Philadelphia, 574p.

Ojo, L.O. and Ola-Adams, B.A., 1996. Measurement of tree diversity in the Nigerian rainforest. *Biodivers. Conserv. 5*(10):1253-1270.

Ors, S., Sahin, U., Ercisli, S. and Esitken, A., 2010. Physical and chemical soil properties of orchid growing areas in Eastern Turkey. *J. Anim. Plant Sci. 8*(3):1044-1050.

Oyun, M.B., Bada, S.O. and Anjah, G.M., 2009. Comparative analysis of the flora composition at the edge and interior of Agulli forest reserve Cameroon. *Res. J. Biol. Sci*., 9(5):431-437.

Padalia, H., Chauhan, N., Porwal, M.C. and Roy, P.S., 2004. Phytosociological observations on tree species diversity of Andaman Islands, India. *Curr. Sci.*:799-806.

Paijmans, K., 1970. An analysis of four tropical rain forest sites in New Guinea. *J. Ecol.* 58(1):77-101.

Panda, P.C., Mahapatra, A.K., Acharya, P.K. and Debata, A.K. 2013. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *Intl. J. Biodivers. Conserv.* 5(10):625-639.

Pandey, S.K. and Shukla, R.P., 2003. Plant diversity in managed sal (*Shorea robusta* Gaertn.) forests of Gorakhpur, India: species composition, regeneration and conservation. : *Biodivers. Conserv*, 12(11):2295-2319.

Parthasarathy, N. and Karthikeyan, R. (1997a). Biodiversity and population density of woody species in a tropical evergreen forest in Courtallum reserve forest, Western Ghats, India. *Trop. Ecol. 38*(2):297-306.

Parthasarathy, N. and Karthikeyan, R. (1997b). Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel Coast, south India. *Biodivers. Conserv.* 6(8):1063-1083.

Parthasarathy, N. 1999. Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. *Biodivers. Conserv.,* 8(10):1365-1381.

Parthasarathy, N. 2001. Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. *Curr. Sci.*:389-393.

Pascal, J.P., 1988. Wet evergreen forests of the Western Ghats of India: ecology, structure, floristic composition and succession. Institut Francais de Pondicherry, Pondicherry, 345p.

Pascal, J.P. and Ramesh, B.R., 1987. A field key to the trees and lianas of the evergreen forests of the Western Ghats (India). *Travaux de la section scientifique et technique. Institut français de Pondichéry*, 23:111-236.

Pascal, J.P., Ramesh, B.R. and Franceschi, D.D. 2004. Wet evergreen forest types of the southern Western Ghats, India. *Trop. Ecol.* 45(2):281-292.

Pascal, J.P., and Pelissier, R., 1996. Structure and floristic composition of a tropical evergreen forest in south-west India. *J. Trop. Ecol.*:191-214.

Paul, C. 2013. Quantification of anthropogenic disturbances in forest as a function of distance to human- a case study from Peechi Vazhani Wildlife Sanctuary. MSc. (For.) thesis, Kerala Agricultural University, Thrissur, 134p.

Pearce, D.W. and Moran, D., 1994. *The economic value of biodiversity. Earthscan: London*, 167 p.

Peverill, K. I., L. A. Sparrow, and D. J. Reuter, eds. *Soil analysis: an interpretation manual*. CSIRO publishing, 1999. 365p.

Phillips, O.L. and Gentry, A.H. 1994. Increasing turnover through time in tropical forests. *Sci.*, 263(5149):954-958.

Peinado, M., Aguirre, J.L., Macías, M.Á. and Delgadillo, J. 2011. A phytosociological survey of the dune forests of the Pacific Northwest. *Plant Biosystems Int. J. Plant Biol.*, 145(1):105-117.

Pianka, E.R., 1966. Latitudinal gradients in species diversity: a review of concepts. *The American Naturalist*, 100(910):33-46.

Pitchairamu, C., Muthuchelian, K. and Siva, N. 2008. Floristic inventory and quantitative vegetation analysis of tropical dry deciduous forest in Piranmalai forest, Eastern Ghats, Tamil Nadu, India. *Ethnobotanical Leaflets*, 2008(1):25.

Pokhriyal, P., Uniyal, P., Chauhan, D.S. and Todaria, N.P., 2010. Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya. *Curr. Sci.*:171-175.

Ponnamperuma, F.N. 1984. Effects of flooding on soils. *Flooding and plant growth*, pp.9-45.

Poorter, L., Bongers, F., van Rompaey, R.S. and de Klerk, M. 1996. Regeneration of canopy tree species at five sites in West African moist forest. *For. Ecol. Manag*. 84(1-3):61-69.

Poorter, L. and Wieringa, J.J., 2001. Biodiversity hotspots in West Africa. In *Tropical Ecosystems: structure, diversity and human welfare: International Conference on Tropical Ecosystems/KN Ganeshaiah, R. Uma Shaanker and KS Bawa.-Sl: Sn, 2001*, 382-385p.

Popma, J., Bongers, F. and del Castillo, J.M. 1988. Patterns in the vertical structure of the tropical lowland rain forest of Los Tuxtlas, Mexico. *Vegetation*, 74(1):81-91.

Pott, R. 2011. Phytosociology: A modern geobotanical method. *Plant Biosystems-An Int. J. Dealing with all Asp. Plant Biol.*, *145*(1):9-18.

Powers, R.F. 1991. Long-term studies. In *Proceedings, Management and Productivity of Western-montane Forest Soils: Boise, ID, April 10-12, 1990* (Vol. 280, p. 70). US Department of Agriculture, Forest Service, Intermountain Research Station.

Pragasan, L.A. and Parthasarathy, N. 2010. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. *Flora*, 205(11):728-73.

Prance, G.T. 1977. Floristic inventory of the tropics: where do we stand? *Annals of the Missouri Botanical Garden*, *64*(4):659-684.

Pratt, P. and Bair, F. 1962. Cation-exchange properties of some acid soils of California. *Hilgardia*, *33*(13):689-706.

Proctor, J., Lee, Y.F., Langley, A.M., Munro, W.R.C. and Nelson, T., 1988. Ecological studies on Gunung Silam, a small ultrabasic mountain in Sabah, Malaysia. I. Environment, forest structure and floristics. *J. Ecol*. 76:320-340.

Rahees, N., Kiran, M. and Vishal, V. 2014. Phytosociological analysis of mangrove forest at Kadalundi-Vallikkunnu community reserve, Kerala. *Int. J. Sci. Tech. 3:*2154-2159.

Rai, S.N. and Proctor, J. 1986. Ecological studies on four rainforests in Karnataka, India: I. Environment, structure, floristics and biomass. *J. Ecol*. 74: 439-454.

Rajendran, A., Aravindhan, V. and Sarvalingam, A. 2014. Biodiversity of the Bharathiar university campus, India: A floristic approach. *International Journal of Biodiversity and Conservation*, 6(4):308-319.

Rajesh, N., Kumar, B.M. and Vijayakumar, N.K. 1996. Regeneration characteristics of selection felled forest gaps of different ages in the evergreen forests of Sholayar, Kerala, India. *J. Trop. For. Sci*. 8:355-368.

Rama, R. 1914. Flowering Plants of Travancore. *Flowering Plants of Travancore,* (Government Press, Trivandrum), 448p.

Ramachandran, V.S. and Swarupanandan, K., 2013. Structure and floristic composition of old-growth wet evergreen forests of Nelliampathy Hills, Southern Western Ghats. *J. For Res.*, 24(1):37-46.

Ramírez-Marcial, N., González-Espinosa, M. and Williams-Linera, G., 2001. Anthropogenic disturbance and tree diversity in montane rain forests in Chiapas, Mexico. *For. Ecol. Manag*., 154(1-2):311-326.

Ramesh, B.R. and Pascal, J.P. 1997. Atlas of endemics of the Western Ghats (India): distribution of tree species in the evergreen and semi-evergreen forests. French Institute, Pondicherry, Publications du department d'ecologie 38p.

Ramya, E.K. and Mownika, S.S.S. 2020. Phytosociological Assessment of Tree Vegetation in Tropical Moist Deciduous Forest of Veerakkal area, Nilgiris, Western Ghats, India. *Indian J. Ecol.* 47(2):480-484.

Rands, M.R., Adams, W.M., Bennun, L., Butchart, S.H., Clements, A., Coomes, D., Entwistle, A., Hodge, I., Kapos, V., Scharlemann, J.P. and Sutherland, W.J. 2010. Biodiversity conservation: challenges beyond 2010. *Sci.* 329(5997):1298-1303.

Rao, P., Barik, S.K., Pandey, H.N. and Tripathi, R.S. 1990. Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. *Vegetation.* 88(2):151-162.

Rao, D.S., Murty, P.P. and Kumar, O.A. 2014. Vegetation composition, tree species diversity and soil types: a case study from the tropical forests of Eastern Ghats of Vizianagaram, India. *Int. J. Curr. Sci.*, (10):78-87.

Rasingam, L. and Parathasarathy, N. 2009. Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. *Trop. Ecol.* 50(1):89.

Rathod, D., Ram, G., Kumar, Y. and Ramola, G.C. 2020. Soil chemical properties of Cedrus deodara (roxb) g. don. forest soil in Garhwal Himalaya, India. *J. Tree Sci.* 39(1):42-51.

Reddy, C.S., Pattanaik, C., Dhal, N.K. and Biswal, A.K. 2006. Vegetation and floristic diversity of Bhitarkanika National Park, Orissa, India. *Indian For.* 132(6):664.

Reddy, C.S., Pattanaik, C., Mohapatra, A. and Biswal, A.K. 2007. Phytosociological observations on tree diversity of tropical forest of Similipal Biosphere Reserve, Orissa, India. *Taiwania*, 52(4):352-359.

Reddy, C.S., Ugle, P., Murthy, M.S.R. and Sudhakar, S. 2008a. Quantitative structure and composition of tropical forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. *Taiwania*, *53*(2):150-156.

Reddy, C.S., Rao, K.T., Krishna, I.S.R. and Javed, S.M.M. 2008b. Vegetation and floristic studies in Nallamalais, Andhra Pradesh, India. *J. Plant Sci. 3*(1):85-91.

Reddy, C.S., Shilpa, B., Giriraj, A., Reddy, K.N. and Rao, K.T. 2010. Structure and floristic composition of tree diversity in tropical dry deciduous forest of Eastern Ghats, Southern Andhra Pradesh, India. *Asian J. Sci. Res. 3*(4):323-330

Reeves, D.W. 1997. The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil Tillage Res. 43*(1-2):131-167.

Reyhan, M.K. and Amiraslani, F. 2006. Studying the relationship between vegetation and physicochemical properties of soil, Case study: Tabas region, Iran. *Pakistan J. Nutr.*, 5(2):169-171.

Richards, P.W., Frankham, R. and Walsh, R.P.D., 1996. *The tropical rain forest: an ecological study*. Cambridge university press.

Richards, J.A. and Richards, J.A., 1999. *Remote sensing digital image analysis* Berlin: Springer. 3, pp. 10-38.

Robertson, G.P., Sollins, P., Ellis, B.G. and Lajtha, K. 1999. Exchangeable ions, pH, and cation exchange capacity. *Standard soil methods for long-term ecological research*, *2*, 462p.

Roby, T.J., Jose, J. and Nair, P.V., 2018. Phytosociological analysis of Myristica swamp forests of Kulathupuzha, Kerala, India. *Curr. Sci.*, *114*(8):1687.

Rodger, W.A. and Panwar, H.S. 1988. Planning a Wildlife Protected Area Network in India. A report. Vol I. and II, Wildlife Institute of India, Dehradun, 339-267 p.

Roy, P.S., Kaul, R.N., Sharma Roy, M.R. and Garbyal, S.S. 1985. Forest-type stratification and delineation of shifting cultivation areas in the eastern part of Arunachal Pradesh using LANDSAT MSS data. *International Journal of Remote Sensing*, *6*(3-4), pp.411-418.

Roxburgh, W. (1820-1824). (Ed. Carey & Wallich). Flora Indica. 2 vols, Parbury, Allen and Co, London, 741p.

Roxburgh, W., Carey, W. and Wallich, N. 1820. Flora indica, Mission Press, 493p.

Ruess, J.O. and Innis, G.S. 1977. A grassland nitrogen flow simulation mode. *Ecology*, *58*, pp.348-429.

Saarsalmi A, Malkonen E, Piirainen S. 2001. Effects of wood ash fertilization on forest soil chemical properties. *Silva Fennica* 35(3): 355-368.

Saenger, P. and Snedaker, S.C. 1993. Pantropical trends in mangrove above-ground biomass and annual litterfall. *Oecologia*, *96*(3):293-299.

Sagar, R. and Singh, J.S. 2003. Predominant phenotypic traits of disturbed tropical dry deciduous forest vegetation in northern India. *Community Ecol.* 4(1):63-71.

Sagar, R., Raghubanshi, A.S. and Singh, J.S., 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. For. Ecol. Manag., 186(1-3):61-71.

Sagar, R. and Singh, J.S. 2005. Structure, diversity, and regeneration of tropical dry deciduous forest of northern India. *Biodivers. Conserv.* 14(4):935-959.

Sagar, R., Pandey, A. and Singh, J.S. 2012. Composition, species diversity, and biomass of the herbaceous community in dry tropical forest of northern India in relation to soil moisture and light intensity. *The Environmentalist*, 32(4):485-493.

Saha, S., Rajwar, G.S. and Kumar, M. 2018. Soil properties along altitudinal gradient in Himalayan temperate forest of Garhwal region. *Acta Ecologica Sinica*, 38(1):1-8.

Sahoo, T., Panda, P.C. and Acharya, L. 2017. Structure, composition and diversity of tree species in tropical moist deciduous forests of Eastern India: a case study of Nayagarh Forest Division, Odisha. *J. For. Res. 28*(6):1219-1230.

Sahoo, T., Acharya, L. and Panda, P.C. 2020. Structure and composition of tree species in tropical moist deciduous forests of Eastern Ghats of Odisha, India, in response to human-induced disturbances. *J. Environ. Sustain.3* (1):69-82.

Sahu, S.C., Dhal, N.K., Reddy, C.S., Pattanaik, C. and Brahmam, M. 2007. Phytosociological study of tropical dry deciduous forest of Boudh district, Orissa, India. *Res. J. For.* 1(2):66-72.

Sahu, S.C., Dhal, N.K. and Mohanty, R.C., 2012. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. *Trop. Ecol.*, 53(2):163-168.

Sarkar, M. and Devi, A., 2014. Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. *Trop. Plant Res. 1*(2):26-36.

Sakthivel, R., Raj, N.J., Pugazhendi, V., Rajendran, S. and Alagappamoses, A. 2011. Remote sensing and GIS for soil erosion prone areas assessment: a case study from Kalrayan hills, part of Eastern Ghats, Tamil Nadu, India. *Arch. Appl. Sci. Res. 3*(6):369-376.

Sankara Rao, K., Raja K Swamy, Deepak Kumar, Arun Singh R. and K. Gopalakrishna Bhat (2019). Flora of Peninsular India. http://peninsular.ces.iisc.ac.in/plants.php? Downloaded on17 January 2021.

Sanalkumar, M.G. 1997. Problems and prospects of biodiversity conservation and management in some forest areas of Kerala, Western Ghats. Ph.D. Thesis submitted to F.R.I., University, Dehradun. 179p.

Sankar, S. and Sanalkumar, M.G. 1998. *Ecological and environmental assessment of forest cover of Kerala with special reference to soil, vegetation and wildlife*. KFRI research report, Trichur.Sapkota, I.P., Tigabu, M. and Odén, P.C., 2009. Spatial distribution, advanced regeneration and stand structure of Nepalese Sal (*Shorea robusta*) forests subject to disturbances of different intensities. *For. Ecol. Manag*. 257(9):1966-1975.

Sarkar, M. and Devi, A. 2014. Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. *Trop. plant Res. 1*(2):26-36.

Sarkar, A.K. 2016. Ecological Studies of Tree Vegetation. *Ecological Studies*, *5*(7):53-59.

Sasidharan, N. 1999. Floristic Diversity of Shenduruny Wildlife Sanctuary, southern Western Ghats, Kerala. *Biodiversity, Taxonomy and Conservation of Flowering Plants. Mentor Books, Calicut*, pp.261-273.

Sasidharan, N. 2002. *Floristic studies in Parambikulam wildlife sanctuary* (No. 246). KFRI Research Report, 408p.

Sasidharan, N. (2004) Biodiversity Documentation for Kerala Part 6: Flowering Plants. Kerala Forest Research Institute, Peechi, 702p.

Sasidharan, N. 2012. Flowering Plants of Kerala – Version 2.0. DVD No. 14. Kerala Forest Research Institute, Peechi.

Satish, K.V. and Reddy, C.S. 2016. Long term monitoring of forest fires in Silent Valley National Park, Western Ghats, India using remote sensing data. *J. Indian Soc. Remote Sens.* 44(2):207-215.

Satyanarayana, B., Raman, A.V., Dehairs, F., Kalavati, C. and Chandramohan, P. 2002. Mangrove floristic and zonation patterns of Coringa, Kakinada Bay, East coast of India. *Wetlands Ecol. Manag.* 10(1):25-37.

Saxena H.O. and Srivastava P. B. L. 1973. Forest communities of Mussoorie. *Trop. Ecol.* 14(2):197-218.

Saxena, A.K. and Singh, J.S. 1982. Quantitative profile structure of certain forests in the Kumaun Himalaya. *Proceedings: Plant Sci. 91*(6):529-549.

Saxena, A.K. and Singh, J.S. 1984. Tree population structure of certain Himalayan forest associations and implications concerning their future composition. *Vegetatio*, *58*(2):61-69.

Scheiner, S.M., 2003. Six types of species-area curves. *Glob. Ecol. Biogeogr., 12*(6):441-447.

Schulz, J.P., 1960. Ecological studies on rain forest in northern Suriname. Mededelingen van het Botanisch Museum en Herbarium van de Rijksuniversiteit te Utrecht, 163(1):1-267.

Schwarz, P.A., Fahey, T.J. and McCulloch, C.E. 2003. Factors controlling spatial variation of tree species abundance in a forested landscape. *Ecology*, *84*(7):1862-1878.

Schoenholtz, S.H., Van Miegroet, H. and Burger, J.A. 2000. A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. *For. Ecol. Manag.* 138(1-3):335-356

Sellamuthu, S. and Lalitha, V. 2010. Plant diversity and phenological pattern in the montane wet temperate forests of the southern Western Ghats, India. *For. studies in China*, *12*(3):116-125.

Senbeta, F., Teketay, D. and Näslund, B.Å. 2002. Native woody species regeneration in exotic tree plantations at Munessa-Shashemene Forest, southern Ethiopia. *New For. 24*(2):131-145.

Shannon, C.E. and Weiner, W. 1963. The mathematical theory of communication Urban University Illinois Press. 125p.

Shankar, U. 2001. A case of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Curr. Sci.* pp.776-786.

Sharma, B.D. 1984. *Flora of Karnataka: Analysis* (No. 2). Botanical Survey of India, Department of Environment, 394p.

Sharma, A. and Samant, S.S. 2013. Diversity, structure and composition of forest communities in Hirb and Shoja catchments of Himachal Pradesh, North West Himalaya, India. *Int .J. Bot.* 9:50-54.

Sharma, C.M., Gairola, S., Ghildiyal, S.K. and Suyal, S. 2010. Physical properties of soils in relation to forest composition in moist temperate valley slopes of the Central Western Himalaya. *J. For. Sci. 26*(2):117-129.

Sharma, C.M., Suyal, S., Gairola, S. and Ghildiyal, S.K. 2009. Species richness and diversity along an altitudinal gradient in moist temperate forest of Garhwal Himalaya. *J. Am. Sci. 5*(5):119-128.

Sharma, P., Rana, J.C., Devi, U., Randhawa, S.S. and Kumar, R. 2014. Floristic diversity and distribution pattern of plant communities along altitudinal gradient in Sangla Valley, Northwest Himalaya. *Sci. World J. 2014*.1-11p.

Sharma, R. 1998. A Study of the effect of long-term protection against grazing on the grassland vegetation at Udaipur. Ph.D. Thesis, submitted to Mohan Lal Sukhdia University, Udaipur.

Sheikh, M.A., Kumar, M. and Bussmann, R.W. 2009. Altitudinal variation in soil organic carbon stock in coniferous subtropical and broadleaf temperate forests in Garhwal Himalaya. *Carbon Balance Manag. 4*(1): 6.

Sheil, D. and Phillip, O. 1995. Evaluating turnover in tropical forests. *Science. 268*(5212):894-896.

Shrivastava, S. and Kanungo, V.K. 2014. Physico-chemical analysis of soils in Surguja district Chattishgarh, India. *Intl. J. Herbal Med. 1*(5):15-18.

Silva, L.D.P.V., Rocha, A.E., Araujo, J.R.G., dos Reis, R.M., Muniz, F.H. and Mesquita, M.L.R. 2016. Vegetation structure of naturally occurring areas of mangaba *Hancornia speciosa* Gomes in the mid-north region of Brazil. *Afr. J. Agric. Res.* 11(32):2937-2946.

Simpson, E.H. 1949. Measurement of diversity. *Nature*, 163(4148):688-688.

Singh, A.K., Prasad, A. and Singh, B., 1986. Availability of phosphorus and potassium and its relationship with some important physico-chemical properties of some forest soils of Pali Range, (Shahdol, MP*). Indian For*.112 (12):1094-1103.

Singh, J.S. and Chaturvedi, R.K., 2017. Diversity of ecosystem types in India: A review. *Proceedings of the Indian National Science Academy*, 83(3):569-594.

Singh, J.S., Singh, S.P., Saxena, A.K. and Rawat, Y.S. 1984. India's Silent Valley and its threatened rain-forest ecosystems. *Environ. Conserv. 11*(3):223-233.

Singh, L. and Singh, J.S., 1991. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Ann. Bot.*, *68*(3):263-273.

Singh, J.S. 2002. The biodiversity crisis: a multifaceted review. *Curr. Sci.*:638-647.

Singh, R. and Shukla, L.N. 2017. Ecological investigation of some selected medicinal plants with special reference to phytosociological aspect in anpara region of sonebhadra district. *Indian J. Sci. Res. 7*(2):159-162.

Sinha, M.K. and Sinha, D. 2013. Biodiversity scenario of lower hills of Baikunthpur (Dist.-Koria) Chhattisgarh (INDIA) with special reference to medicinal plants. *J. Med. Plants Res. 7*(27):2028-2033.

Solbrig, O.T. 1991. From genes to ecosystems: a research agenda for biodiversity: report of a IUBS-SCOPE-UNESCO workshop, Harvard Forest, Petersham, Ma., USA, June 27-July 1, 1991.

Sonon, L.S., D.E. Kissel, and U. Saha. 2014. Cation exchange capacity and base saturation. University of Georgia Extension. Retrieved Sept 25th, 2019 http://extension.uga.edu/publications/files/pdf/C%201040_1.PDF.

Sreejith, K. A., Chandrashekara, U. M., Nirmesh, T. K. and Sreekumar, V. B. 2016. Tree species composition and distribution pattern in a myristica swamp of northern Kerala, India. *Curr. World Environ.* 11:743.

Srinivas, V. and Parthasarathy, N. 2000. Comparative analysis of tree diversity and dispersion in the tropical lowland evergreen forest of Agumbe, Central Western Ghats, India. *Trop. Biodivers. 7*(1):45-60.

Steege, H.T., Sabatier, D., Castellanos, H., Van Andel, T., Duivenvoorden, J., de Oliveira, A.A., Ek, R., Lilwah, R., Maas, P. and Mori, S. 2000. An analysis of the floristic composition and diversity of Amazonian forests including those of the Guiana Shield. *J. Trop. Ecol.*:801-828.

Strong, W.L. and La Roi, G.H. 1985. Root density-soil relationships in selected boreal forests of central Alberta, Canada. *For. Ecol. Manag. 12*(3-4):233-251.

Su, Y., Guo, Q., Fry, D.L., Collins, B.M., Kelly, M., Flanagan, J.P. and Battles, J.J. 2016. A vegetation mapping strategy for conifer forests by combining airborne LiDAR data and aerial imagery. *Can. J. Remote Sens. 42*(1):1-15.

Subramanyam, K. and Nayar, M.P. 1974. Vegetation and phytogeography of the Western Ghats. In *Ecology and biogeography in India*, Springer, Dordrecht, pp. 178-196.

Sudduth, K.A., N.R. Kitchen, W.J. Wiebold, W.D. Batchelor, G.A. Bollero, D.G. Bullock et al. 2005. Relating apparent electrical conductivity to soil properties across the north-central USA. *Comput. Electron. Agric*. 46: 263-283.

Sudeesh, S. and Reddy, S. 2012. Vegetation and Land Cover Mapping of Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India using Remote Sensing and GIS. *Int. J. Geomat. Geosci. 2:*955-963.

Sukumar, R., Dattaraja, H.S., Suresh, H.S., Radhakrishnan, J., Vasudeva, R., Nirmala, S. and Joshi, N.V. 1992. Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, southern India. *Curr. Sci.*:608-616.

Sundarapandian, S. and Swamy, P., 1998. Variation in fine-root biomass and net primary productivity due to conversion of tropical forests into plantation crops and agroecosystems. In *Root Demographics and Their Efficiencies in Sustainable Agriculture, Grasslands and Forest Ecosystems*. Springer, Dordrecht. 369-382.

Sundarapandian, S.M. and Swamy, P.S. 2000. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. *J. Trop. For. Sci.* pp.104-123.

Swaine, M.D. and Hall, J.B., 1988. The mosaic theory of forest regeneration and the determination of forest composition in Ghana. *J. Trop. Ecol.*, *4*(3):253-269.

Swamy, H.R. and Proctor, J. 1994. Rain forests and their soils in the Sringeri area of the Indian Western Ghats. *Glob. Ecol. Biogeogr.,* 140-154.

Swamy, P.S., Sundarapandian, S.M., Chandrasekar, P. and Chandrasekaran, S., 2000. Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India. *Biodiversity & Conservation*, *9*(12):1643-1669.

Swamy, S.L., Dutt, C.B.S., Murthy, M.S.R., Mishra, A. and Bargali, S.S. 2010. Floristic and dry matter dynamics of tropical wet evergreen forests of Western Ghats, India. *Curr. Sci. 99*(3):353-364.

Tashi, S., Singh, B., Keitel, C. and Adams, M. 2016. Soil carbon and nitrogen stocks in forests along an altitudinal gradient in the eastern Himalayas and a meta-analysis of global data. *GCB Bioenergy.* 22(6):2255-2268.

Thakur, T.K., 2018. Diversity, composition and structure of understorey vegetation in the tropical forest of Achanakmaar Amarkantak Biosphere Reserve, India. *J. Environ. Sustain.* 1(3):279-293.

Torahi, A.A. and Rai, S.C., 2011. Land cover classification and forest change analysis, using satellite imagery-a case study in Dehdez area of Zagros Mountain in Iran. *J. Geogr. Inf. Syst.*, 3(01):1.

Tracey, J.G., 1969. Edaphic differentiation of some forest types in eastern Australia: I. Soil physical factors. *J. Ecol.:*805-816.

Tripathi, K.P. and Singh, B., 2009. Species diversity and vegetation structure across various strata in natural and plantation forests in Katerniaghat Wildlife Sanctuary, North India. *Trop. Ecol. 50*(1):191.

Tsui, C.C., Chen, Z.S. and Hsieh, C.F. 2004. Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan. *Geoderma. 123*(1-2):131-142.

Uhl, C., Clark, K., Clark, H. and Murphy, P., 1981. Early plant succession after cutting and burning in the upper Rio Negro region of the Amazon basin. *J. Ecol.*, 631-649.

Valencia, R., Balslev, H. and Miño, G.P.Y. 1994. High tree alpha-diversity in Amazonian Ecuador. *Biodivers. Conserv. 3*(1):21-28.

Varghese, V. and Kumar, B. M. 1997. Ecological observations in the fresh water swamp forests of southern Kerala, India. *J. Trop. For. Sci.* 9:299-314.

Varghese, A.O. and Menon, A.R.R. 1998. Vegetation characteristics of southern secondary moist mixed deciduous forests of Agasthyamalai region of Kerala. *Indian J. For. 21*(4):639-644.

Varghese, A.O. and Balasubramanyan, K. 1999. Structure, composition and diversity of the tropical wet evergreen forest of the Agasthyamalai region of Kerala, Western Ghats. *J. S. Asian Nat. Hist.*, *4*(1):87-98.

Varghese, A. O. and Menon, A.R.R. 1999. Floristic Composition, Dynamics and Diversity of Myristica Swamp Forests of Southern-Western Ghats, Kerala. *Indian For.* 125:775-783.

Verma, R.K., Shadangi, D.K. and Totey, N.G. 1999. Species diversity under plantation raised on a degraded land. *Malaysian For. 62*(2):95-106.

Vijayan, V., Rahees, N. and Vidyasagaran, K. 2015. Floristic diversity and structural analysis of mangrove forests at Ayiramthengu, Kollam district, Kerala. *J. Plant Dev. Sci. 7*(2):105-108.

Vimhaseno, N. and Nagaraja, B.C., 2019. Tree diversity and endemism pattern in Makutta Wildlife Range, Western Ghats, India. *Indian For.*, *145*(7):631-636.

Wallace, J., Behn, G. and Furby, S. 2006. Vegetation condition assessment and monitoring from sequences of satellite imagery. *Ecol. Manag. Restor. 7*:31-S36.

Walkey, A. and Black, I.A.1934. An examination of the detjareff method for determining soil organic matter and a proposed modification to the chronic titration method. Soil Sci. 37:29-38.

Waring, R.H. and Schlesinger, W.H. 1985. Forest ecosystems. *Analysis at multiples scales*, p.55.

Wardell-Johnson, G. and Williams, M., 1996. A floristic survey of the Tingle Mosaic, south-western Australia: applications in land use planning and management. *J. R. Soc. West Aust. 79*:249.

Wattenberg, I. 1995. Tree species diversity of a premontane rain forest in the Cordillera de Tilaran, Costa Rica. *Ecotropica,* 1:21-30.

Whalley, W.R., Dumitru, E. and Dexter, A.R. 1995. Biological effects of soil compaction. *Soil Tillage Res.*, *35*(1-2):53-68.

Whitmore, T.C., 1984. *Tropical rain forests of the Par East*. Oxford. Clarendon Press. 352p.

Wiesmeier, M., Urbanski, L., Hobley, E., Lang, B., von Lützow, M., Marin-Spiotta, E., van Wesemael, B., Rabot, E., Ließ, M., Garcia-Franco, N. and Wollschläger, U. 2019. Soil organic carbon storage as a key function of soils-a review of drivers and indicators at various scales. *Geoderma*, *333*, pp.149-162.

Wight, R. and Arnott, G.A.W. 1834. *Prodromus Florae Peninsulae Indiae Orientalis: containing abridged descriptions of the plants found in the peninsula of British India, arranged according to the natural system* (Vol. 1). Parbury, Allen & Company.

Williston, H.L. and LaFayette, R. 1978. Species suitability and pH of soils in southern forests. *For. Manag. Bull.* 1-6p.

Zegeye, H., Teketay, D. and Kelbessa, E. 2006. Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. *Flora 201*(6):483-498.

Zinke, P.J., 1962. The pattern of influence of individual forest trees on soil properties. *Ecol. 43*(1):130-133.

Zornoza, R., Mataix-Solera, J., Guerrero, C., Arcenegui, V., Mayoral, A.M., Morales, J. and Mataix-Beneyto, J. 2007. Soil properties under natural forest in the Alicante Province of Spain. *Geoderma*, *142*(3-4):334-341.

PHYTOSOCIOLOGICAL AND EDAPHIC ATTRIBUTES OF FOREST ECOSYSTEMS OF SHENDURNEY WILDLIFE SANCTUARY, KOLLAM, KERALA

By

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ABSTRACT OF THE THESIS

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Abstract

The present study was carried out with the primary objective of studying the tree species diversity, structure, and composition, physicochemical attributes and land use and land cover change of forest ecosystems of Shendurney Wildlife Sanctuary, Kollam, Kerala viz., west coast tropical evergreen, west coast tropical semi-evergreen, southern secondary moist deciduous, myristica swamp, and tropical hilltop forest. The stratified random sampling approach was adopted for vegetation assessment with a sampling plot of 20 m × 20 m. The regeneration pattern of the tree species was studied from the plots of 5 m × 5 m for the tree saplings and 1 m × 1 m for the tree seedlings from each of the 20 m × 20m plots. The soil sample was collected horizon-wise up to 1 m from each of the forest ecosystems. The land use and land cover was studied using the supervised classification with Maximum Likelihood Algorithm and change detection comparison approach using the Landsat Enhanced Thematic Mapper (ETM±) and Landsat 8 OLI-TIRS using the data capture on July 01, 2001, and January 14, 2018.

A total of 119 species with a density of 1053.50 ha^{-1} and 50.04 m^2 ha^{-1} basal area were recorded from the west coast tropical evergreen, 101 species with the density of 914.55 ha^{-1} with the basal area of 41.64 m^2 ha^{-1} basal area from west coast semi-evergreen, 58 species with a density of 876.97 ha^{-1} with the basal area of 26.88 m^2 ha^{-1} from the moist deciduous, 33 species with a density of 1144.44 ha^{-1} and the basal area of 33.93 m^2 ha^{-1} from the myristica swamp, and 44 species with a density of 619 ha^{-1} and basal area of 16.93 m^2 ha^{-1} from the tropical hilltop forest, respectively. The girth class distribution of the forest ecosystems varies significantly, with the west coast tropical evergreen forest showed the reversed J-shaped distribution. And a completely L-shaped pattern for the west coast semi-evergreen and southern secondary moist deciduous forest, whereas inverted iJ-shape in the tropical hilltop forest. The percent species endemism of 85.44% was recorded in the myristica swamp forest, 79.15% for the tropical hilltop forest, 55.58% for the west coast tropical evergreen forest, 40.71% for west coast tropical semi-evergreen forest, and the lowest (29.26%) for the moist deciduous forest.

The dominant families in the west coast tropical evergreen forest are Dipterocarpaceae (FIV=24.92), Clusiaceae (FIV=21.40), and Myrtaceae (FIV=20.78). The families Euphorbiaceae (FIV=31.68), Dipterocarpaceae (FIV=24.18), and Rubiaceae (FIV=18.99) were dominant for the west coast semi-evergreen forest. In the

Moist deciduous forest, the dominant families are Euphorbiaceae (FIV=52.99), Combretaceae (FIV=41.23), and Malvaceae (31.73). For the myristica swamp forest, the families Myristicaceae (FIV=149.01), Dipterocarpaceae (FIV=41.08), and Anacardiaceae (FIV=25.86) are dominant. The families Lauraceae (FIV=69.92) and Clusiaceae (FIV=35.71) are dominant in the tropical hilltop forest.

The Shannon-Weiner and Simpson indices were found at 4.10 and 0.97 for west coast tropical evergreen, 4.09 and 0.97 for west coast semi-evergreen, 3.22 and 0.92 for the Southern secondary moist deciduous, 3.88 and 0.95. The lowest value (2.70 and 088) was reported for the myristica swamp forest. The diversity indices of west coast evergreen and west coast semi-evergreen showed no significant variation. The Margalef value was reported higher for the evergreen forest. Moreover, this study found that most tree species showed a contagious distribution pattern for a tree, saplings, and seedling levels, with very few showing the uniform distribution pattern of distribution.

The tree species regeneration was adequate for most forest ecosystems, with the highest density (3,582 ha^{-1} saplings and 27,777 ha^{-1} seedlings) recorded in the west coast tropical evergreen forest. However, most dominant species showed relatively good regeneration, especially in the west coast tropical evergreen and west coast tropical semi-evergreen forests. The diversity indices of the regenerating seedlings and saplings do not vary significantly across all the forest ecosystems.

Across the forest ecosystems, the soil is slightly acidic with a moderate amount of soil organic carbon. The soil percent organic carbon, Cation Exchange Capacity, and electrical conductivity are relatively higher in the first horizon and showed decreasing trend across all the forest ecosystems. The bulk density showed low in the first horizon and increased with depth ecosystems. The higher bulk density was recorded for the Myristica swamp forest.

The land use and land cover analysis indicated a rigorous land cover change in the forest ecosystems. It showed a significant increase in the proportion of degraded forest from 21.31% in 2001 to 22.97% in 2018. Substantial loss in the moist deciduous forest from 27.11 % in 2001 to 17.23 % in 2018 and semi-evergreen forest from 26.91 % in 2001 to 18.98 % in 2018 was reported. Anthropogenic activities such as pressure on land for agriculture, expansion of human settlements, forest fire, and plantation establishment were found to be the major factors that led to the drastic changes in the land cover of forest ecosystems of Shendurney Wildlife sanctuary.

Appendices

APPENDIX

Appendix I: IVI values of tree species of West Coast Tropical Evergreen Forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BA	RBA	IVI
1	*Mesua ferrea*	6.04	0.13	72.50	6.88	48.00	4.09	0.78	1.55	12.52
2	*Xanthophyllum arnottianum*	7.85	0.20	78.50	7.45	40.00	3.41	0.13	0.26	11.12
3	*Cullenia exarillata*	6.24	0.18	53.00	5.03	34.00	2.90	1.24	2.47	10.39
4	*Vateria indica*	4.06	0.11	36.50	3.46	36.00	3.07	1.29	2.56	9.10
5	*Diospyros candolleana*	4.45	0.10	49.00	4.65	44.00	3.75	0.23	0.46	8.86
6	*Gluta travancorica*	4.20	0.14	31.50	2.99	30.00	2.56	1.42	2.81	8.36
7	*Dysoxylum malabaricum*	6.56	0.21	52.50	4.98	32.00	2.73	0.31	0.62	8.33
8	*Kingiodendron pinnatum*	1.40	0.14	3.50	0.33	10.00	0.85	2.74	5.44	6.62
9	*Baccaurea courtallensis*	4.53	0.15	34.00	3.23	30.00	2.56	0.07	0.15	5.93
10	*Persea macrantha*	3.53	0.12	26.50	2.52	30.00	2.56	0.41	0.82	5.89
11	*Carallia brachiata*	3.18	0.09	27.00	2.56	34.00	2.90	0.19	0.38	5.84
12	*Dalbergia lanceolaria*	1.00	0.50	0.50	0.05	2.00	0.17	2.78	5.51	5.73
13	*Syzygium densiflora*	5.10	0.26	25.50	2.42	20.00	1.70	0.71	1.41	5.54
14	*Hopea parviflora*	3.50	0.18	17.50	1.66	20.00	1.70	0.99	1.96	5.32
15	*Syzygium mundagam*	3.08	0.12	20.00	1.90	26.00	2.22	0.60	1.20	5.31
16	*Anacolosa densiflora*	3.20	0.11	24.00	2.28	30.00	2.56	0.12	0.23	5.06
17	*Schleichera oleosa*	2.53	0.08	19.00	1.80	30.00	2.56	0.30	0.59	4.95
18	*Lannea coromandelica*	3.00	0.75	3.00	0.28	4.00	0.34	1.98	3.93	4.56
19	*Ficus dalhousiae*	2.50	0.63	2.50	0.24	4.00	0.34	1.94	3.84	4.42
20	*Syzygium cumuni*	2.60	0.26	6.50	0.62	10.00	0.85	1.47	2.91	4.38
21	*Knema attenuata*	2.73	0.12	15.00	1.42	22.00	1.87	0.41	0.81	4.11
22	*Lophopetalum wightianum*	2.57	0.18	9.00	0.85	14.00	1.19	0.94	1.87	3.91
23	*Hopea ponga*	3.22	0.18	14.50	1.38	18.00	1.53	0.48	0.95	3.86

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BA	RBA	IVI
24	*Artocarpus hirsutus*	1.00	0.50	0.50	0.05	2.00	0.17	1.77	3.51	3.72
25	*Cinnamomum malabatrum*	2.36	0.11	13.00	1.23	22.00	1.87	0.21	0.42	3.53
26	*Symplocos cochinchinensis*	5.00	0.31	20.00	1.90	16.00	1.36	0.13	0.26	3.52
27	*Dipterocarpus indicus*	3.00	0.50	4.50	0.43	6.00	0.51	1.21	2.40	3.34
28	*Antiaris toxicaria*	2.00	1.00	1.00	0.09	2.00	0.17	1.54	3.05	3.32
29	*Psydrax dicoccos*	4.00	0.25	16.00	1.52	16.00	1.36	0.15	0.30	3.19
30	*Goniothalamus rhynchantherus*	3.29	0.23	11.50	1.09	14.00	1.19	0.45	0.89	3.18
31	*Vitex altissma*	1.00	0.25	1.00	0.09	4.00	0.34	1.36	2.69	3.13
32	*Litsea coriacea*	3.63	0.23	14.50	1.38	16.00	1.36	0.10	0.19	2.93
33	*Ixora brachiata*	5.33	0.44	16.00	1.52	12.00	1.02	0.20	0.39	2.93
34	*Syzygium hemisphericum*	2.50	0.21	7.50	0.71	12.00	1.02	0.56	1.11	2.84
35	*Diospyros foliolosa*	2.25	0.28	4.50	0.43	8.00	0.68	0.87	1.72	2.83
36	*Poeciloneuron indicum*	4.33	0.36	13.00	1.23	12.00	1.02	0.27	0.53	2.79
37	*Myristica malabarica*	2.67	0.22	8.00	0.76	12.00	1.02	0.49	0.96	2.75
38	*Elaeocarpus serratus*	2.38	0.15	9.50	0.90	16.00	1.36	0.22	0.44	2.70
39	*Xylopia parvifolia*	1.60	0.16	4.00	0.38	10.00	0.85	0.74	1.46	2.69
40	*Palaquium ellipticum*	5.00	0.83	7.50	0.71	6.00	0.51	0.67	1.33	2.56
41	*Stereospermum colais*	3.33	0.56	5.00	0.47	6.00	0.51	0.77	1.53	2.52
42	*Aporosa cardiosperma*	3.00	0.21	10.50	1.00	14.00	1.19	0.17	0.33	2.52
43	*Nothopegia colebrookiana*	3.71	0.27	13.00	1.23	14.00	1.19	0.03	0.05	2.48
44	*Terminalia bellirica*	4.50	1.13	4.50	0.43	4.00	0.34	0.79	1.57	2.33
45	*Haldina cordifolia*	1.33	0.11	4.00	0.38	12.00	1.02	0.45	0.88	2.29
46	*Dipterocarpus bourdillonii*	3.40	0.34	8.50	0.81	10.00	0.85	0.28	0.55	2.21
47	*Cinnamomum sulphuratum*	2.71	0.19	9.50	0.90	14.00	1.19	0.05	0.10	2.19
48	*Elaeocarpus munronii*	2.80	0.28	7.00	0.66	10.00	0.85	0.34	0.67	2.19
49	*Dimocarpus longan*	3.00	0.25	9.00	0.85	12.00	1.02	0.15	0.30	2.17

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BA	RBA	IVI
50	*Miliusa wightiana*	3.67	0.31	11.00	1.04	12.00	1.02	0.05	0.10	2.17
51	*Syzygium gardnerii*	1.00	0.25	1.00	0.09	4.00	0.34	0.87	1.72	2.15
52	*Polyalthia fragrans*	2.67	0.22	8.00	0.76	12.00	1.02	0.17	0.33	2.12
53	*Lagerstroemia microcarpa*	2.50	0.31	5.00	0.47	8.00	0.68	0.47	0.92	2.08
54	*Terminalia paniculata*	1.00	0.25	1.00	0.09	4.00	0.34	0.83	1.64	2.07
55	*Turpinia malabarica*	3.33	0.56	5.00	0.47	6.00	0.51	0.49	0.98	1.97
56	*Agrostistachys borneensis*	5.25	0.66	10.50	1.00	8.00	0.68	0.13	0.26	1.93
57	*Mangifera indica*	3.00	0.50	4.50	0.43	6.00	0.51	0.49	0.96	1.90
58	*Pterospermum diversifolium*	4.00	0.50	8.00	0.76	8.00	0.68	0.23	0.46	1.90
59	*Mallotus philippensis*	2.00	0.17	6.00	0.57	12.00	1.02	0.13	0.26	1.85
60	*Flacourtia jangomas*	1.00	0.50	0.50	0.05	2.00	0.17	0.82	1.62	1.84
61	*Hydnocarpus pentandrus*	2.25	0.28	4.50	0.43	8.00	0.68	0.34	0.68	1.79
62	*Calophyllum polyanthum*	4.00	0.67	6.00	0.57	6.00	0.51	0.35	0.70	1.78
63	*Otonephelium stipulaceum*	3.60	0.36	9.00	0.85	10.00	0.85	0.03	0.06	1.77
64	*Myristica dactyloides*	3.00	0.50	4.50	0.43	6.00	0.51	0.39	0.78	1.72
65	*Myristica fatua*	1.40	0.14	3.50	0.33	10.00	0.85	0.26	0.52	1.70
66	*Myristica fragrans*	1.00	0.25	1.00	0.09	4.00	0.34	0.64	1.26	1.70
67	*Canarium strictum*	1.00	0.17	1.50	0.14	6.00	0.51	0.47	0.92	1.58
68	*Ficus tsjakela*	1.00	0.25	1.00	0.09	4.00	0.34	0.57	1.13	1.56
69	*Croton malabaricus*	1.40	0.14	3.50	0.33	10.00	0.85	0.19	0.37	1.56
70	*Maesa indica*	4.00	0.50	8.00	0.76	8.00	0.68	0.05	0.11	1.55
71	*Macaranga peltata*	2.33	0.39	3.50	0.33	6.00	0.51	0.32	0.64	1.48
72	*Bhesa indica*	1.80	0.18	4.50	0.43	10.00	0.85	0.10	0.20	1.48
73	*Nothopodytes nimmoniana*	8.50	2.13	8.50	0.81	4.00	0.34	0.11	0.22	1.37
74	*Litsea oleoides*	4.00	1.00	4.00	0.38	4.00	0.34	0.32	0.64	1.36
75	*Litsea wightiana*	1.50	0.38	1.50	0.14	4.00	0.34	0.41	0.82	1.30

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BA	RBA	IVI
76	*Ceiba pentendra*	1.00	0.25	1.00	0.09	4.00	0.34	0.44	0.86	1.30
77	*Garcinia xanthochymus*	2.50	0.63	2.50	0.24	4.00	0.34	0.35	0.69	1.27
78	*Diosypros buxifolia*	2.67	0.44	4.00	0.38	6.00	0.51	0.18	0.36	1.25
79	*Paracroton pendalus*	4.50	1.13	4.50	0.43	4.00	0.34	0.21	0.41	1.18
80	*Diosypros paniculata*	4.50	1.13	4.50	0.43	4.00	0.34	0.17	0.34	1.11
81	*Hopea malabarica*	3.00	0.75	3.00	0.28	4.00	0.34	0.23	0.47	1.09
82	*Mastixia arborea*	3.50	0.88	3.50	0.33	4.00	0.34	0.20	0.40	1.07
83	*Actinodaphne malabarica*	2.00	0.33	3.00	0.28	6.00	0.50	0.14	0.28	1.07
84	*Celtis philippensis*	1.67	0.28	2.50	0.24	6.00	0.51	0.15	0.30	1.05
85	*Gomphandra coriacea*	2.00	0.33	3.00	0.28	6.00	0.51	0.11	0.23	1.02
86	*Hydnocarpus alpina*	3.50	0.88	3.50	0.33	4.00	0.34	0.16	0.32	0.99
87	*Gordonia obtusa*	3.50	0.88	3.50	0.33	4.00	0.34	0.13	0.26	0.94
88	*Humboldtia deccurrens*	2.00	0.50	2.00	0.19	4.00	0.34	0.19	0.39	0.92
89	*Sapindus laurifolius*	1.00	0.50	0.50	0.05	2.00	0.17	0.33	0.66	0.88
90	*Garcinia travancorica*	2.00	1.00	1.00	0.09	2.00	0.17	0.31	0.61	0.87
91	*Pongamia pinnata*	1.67	0.28	2.50	0.24	6.00	0.51	0.05	0.10	0.85
92	*Neolitsea scrobiculata*	3.00	0.75	3.00	0.28	4.00	0.34	0.11	0.22	0.84
93	*Glochidion zeylanicum*	2.50	0.63	2.50	0.24	4.00	0.34	0.11	0.22	0.80
94	*Bischofia javonica*	1.50	0.38	1.50	0.14	4.00	0.34	0.16	0.31	0.79
95	*Garcinia morella*	1.50	0.38	1.50	0.14	4.00	0.34	0.15	0.30	0.78
96	*Garcinia cowa*	2.00	0.50	2.00	0.19	4.00	0.34	0.11	0.22	0.75
97	*Holigarna arnottiana*	1.00	0.25	1.00	0.09	4.00	0.34	0.14	0.28	0.72
98	*Melia dubia*	1.00	0.50	0.50	0.05	2.00	0.17	0.25	0.49	0.71
99	*Meiogyne pannosa*	2.50	0.63	2.50	0.24	4.00	0.34	0.06	0.12	0.70
100	*Vernonia travancorica*	1.50	0.38	1.50	0.14	4.00	0.34	0.10	0.19	0.67
101	*Ardisia rhomboidea*	2.00	0.50	2.00	0.19	4.00	0.34	0.07	0.13	0.66

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BA	RBA	IVI
102	*Strombosia ceylanica*	2.00	1.00	1.00	0.09	2.00	0.17	0.20	0.40	0.66
103	*Chionanthus mala-elongi*	2.00	0.50	2.00	0.19	4.00	0.34	0.07	0.13	0.66
104	*Garcinia gummi-gutta*	2.00	0.50	2.00	0.19	4.00	0.34	0.06	0.11	0.64
105	*Aglaia malabarica*	1.00	0.25	1.00	0.09	4.00	0.34	0.09	0.19	0.62
106	*Aglaia simplicifolia*	1.50	0.38	1.50	0.14	4.00	0.34	0.07	0.14	0.62
107	*Aglaia barberi*	1.00	0.25	1.00	0.09	4.00	0.34	0.08	0.16	0.60
108	*Eugenia bracheata*	1.50	0.38	1.50	0.14	4.00	0.34	0.03	0.07	0.55
109	*Erythrina variegata*	6.00	3.00	3.00	0.28	2.00	0.17	0.02	0.03	0.49
110	*Murayya paniculata*	1.00	0.25	1.00	0.09	4.00	0.34	0.02	0.04	0.48
111	*Ehretia canarensis*	1.00	0.50	0.50	0.05	2.00	0.17	0.13	0.25	0.47
112	*Dillenia pentagyna*	2.00	1.00	1.00	0.09	2.00	0.17	0.07	0.14	0.41
113	*Celtis timorensis*	3.00	1.50	1.50	0.14	2.00	0.17	0.03	0.06	0.37
114	*Memocylon umbellatum*	3.00	1.50	1.50	0.14	2.00	0.17	0.03	0.05	0.37
115	*Cinnamomum wightii*	1.00	0.50	0.50	0.05	2.00	0.17	0.07	0.14	0.36
116	*Atalantia racemosa*	2.00	1.00	1.00	0.09	2.00	0.17	0.03	0.05	0.32
117	*Michelia nilagirica*	1.00	0.50	0.50	0.05	2.00	0.17	0.04	0.08	0.30
118	*Bixa orellana*	1.00	0.50	0.50	0.05	2.00	0.17	0.04	0.08	0.29
119	*Dendrocnide sinuata*	1.00	0.50	0.50	0.05	2.00	0.17	0.02	0.04	0.25

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; FIV- Family importance value of the species

Appendix II: IVI of tree saplings of West Coast Tropical Evergreen Forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Mesua ferrea*	2.03	0.05	320.93	8.96	39.53	8.59	17.55
2	*Dysoxylum malabaricum*	3.25	0.17	241.86	6.75	18.60	4.04	10.79
3	*Xanthophyllum arnottianum*	2.81	0.15	209.30	5.84	18.60	4.04	9.88
4	*Diospyros candolleana*	2.41	0.12	190.70	5.32	19.77	4.29	9.62
5	*Cullenia exarillata*	2.92	0.19	176.74	4.94	15.12	3.28	8.22
6	*Carallia brachiata*	2.67	0.19	148.84	4.16	13.95	3.03	7.19
7	*Baccaurea courtallensis*	1.93	0.12	125.58	3.51	16.28	3.54	7.04
8	*Hopea parviflora*	1.79	0.11	116.28	3.25	16.28	3.54	6.78
9	*Vateria indica*	1.77	0.12	106.98	2.99	15.12	3.28	6.27
10	*Gluta travancorica*	1.46	0.10	88.37	2.47	15.12	3.28	5.75
11	*Schleichera oleosa*	1.18	0.09	60.47	1.69	12.79	2.78	4.47
12	*Persea macrantha*	2.25	0.24	83.72	2.34	9.30	2.02	4.36
13	*Anacolosa densiflora*	1.67	0.16	69.77	1.95	10.47	2.27	4.22
14	*Cinnamomum malabatrum*	1.50	0.16	55.81	1.56	9.30	2.02	3.58
15	*Syzygium mundagam*	1.57	0.19	51.16	1.43	8.14	1.77	3.20
16	*Symplocos cochinchinensis*	2.00	0.29	55.81	1.56	6.98	1.52	3.07
17	*Agrostistachys borneensis*	1.83	0.26	51.16	1.43	6.98	1.52	2.94
18	*Knema attenuata*	1.83	0.26	51.16	1.43	6.98	1.52	2.94
19	*Goniothalamus rhynchantherus*	2.75	0.59	51.16	1.43	4.65	1.01	2.44
20	*Cinnamomum sulphuratum*	1.80	0.31	41.86	1.17	5.81	1.26	2.43
21	*Myristica dactylaides*	1.80	0.31	41.86	1.17	5.81	1.26	2.43

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
22	*Myristica malabarica*	1.80	0.31	41.86	1.17	5.81	1.26	2.43
23	*Psydrax dicoccos*	1.80	0.31	41.86	1.17	5.81	1.26	2.43
24	*Syzygium hemisphericum*	1.80	0.31	41.86	1.17	5.81	1.26	2.43
25	*Diosypros buxifolia*	2.50	0.54	46.51	1.30	4.65	1.01	2.31
26	*Lophopetalum wightianum*	1.60	0.28	37.21	1.04	5.81	1.26	2.30
27	*Otonephelium stipulaceum*	1.40	0.24	32.56	0.91	5.81	1.26	2.17
28	*Polyalthia fragrans*	1.40	0.24	32.56	0.91	5.81	1.26	2.17
29	*Dipterocarpus bourdillonii*	2.00	0.43	37.21	1.04	4.65	1.01	2.05
30	*Strombosia ceylanica*	2.00	0.43	37.21	1.04	4.65	1.01	2.05
31	*Croton malabaricus*	1.75	0.38	32.56	0.91	4.65	1.01	1.92
32	*Miliusa wightiana*	1.50	0.32	27.91	0.78	4.65	1.01	1.79
33	*Macaranga peltata*	1.25	0.27	23.26	0.65	4.65	1.01	1.66
34	*Dimocarpus longan*	2.00	0.57	27.91	0.78	3.49	0.76	1.54
35	*Hydnocarpus alpina*	2.00	0.57	27.91	0.78	3.49	0.76	1.54
36	*Nothopegia celebrookiana*	1.67	0.48	23.26	0.65	3.49	0.76	1.41
37	*Syzygium densiflorum*	1.67	0.48	23.26	0.65	3.49	0.76	1.41
38	*Aporosa cardiosperma*	3.00	1.29	27.91	0.78	2.33	0.51	1.28
39	*Elaeocarpus munronii*	3.00	1.29	27.91	0.78	2.33	0.51	1.28
40	*Hopea racophloea*	3.00	1.29	27.91	0.78	2.33	0.51	1.28
41	*Hydnocarpus pentandra*	3.00	1.29	27.91	0.78	2.33	0.51	1.28
42	*Actinodaphne malabarica*	1.33	0.38	18.60	0.52	3.49	0.76	1.28
43	*Diosypros foliosa*	1.33	0.38	18.60	0.52	3.49	0.76	1.28
44	*Nothapodytes nimmoniana*	2.50	1.08	23.26	0.65	2.33	0.51	1.15

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
45	*Palaquium ellipticum*	2.50	1.08	23.26	0.65	2.33	0.51	1.15
46	*Pongamia pinnnata*	2.50	1.08	23.26	0.65	2.33	0.51	1.15
47	*Litsea wightiana*	1.00	0.29	13.95	0.39	3.49	0.76	1.15
48	*Syzygium cumini*	1.00	0.29	13.95	0.39	3.49	0.76	1.15
49	*Ixora brachiata*	2.00	0.86	18.60	0.52	2.33	0.51	1.02
50	*Macaranga indica*	2.00	0.86	18.60	0.52	2.33	0.51	1.02
51	*Murraya paniculata*	2.00	0.86	18.60	0.52	2.33	0.51	1.02
52	*Ardisia rhomboidea*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
53	*Atalantia racemosa*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
54	*Bhesa indica*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
55	*Elaeocarpus serratus*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
56	*Garcinia gummi-gutta*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
57	*Holigarna arnottiana*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
58	*Litsea oleoides*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
59	*Mallotus philippensis*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
60	*Mastixia arborea arborea*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
61	*Meiogyne pannosa*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
62	*Paracroton pendalus*	1.50	0.65	13.95	0.39	2.33	0.51	0.89
63	*Calophyllum polyanthum*	4.00	3.44	18.60	0.52	1.16	0.25	0.77
64	*Glochidion zeylanicus*	1.00	0.43	9.30	0.26	2.33	0.51	0.76
65	*Hopea ponga*	1.00	0.43	9.30	0.26	2.33	0.51	0.76
66	*Litsea coriacea*	1.00	0.43	9.30	0.26	2.33	0.51	0.76
67	*Mangifera indica*	1.00	0.43	9.30	0.26	2.33	0.51	0.76

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
68	*Measa indica*	1.00	0.43	9.30	0.26	2.33	0.51	0.76
69	*Xylopia parvifolia*	1.00	0.43	9.30	0.26	2.33	0.51	0.76
70	*Artocarpus hirsutus*	3.00	2.58	13.95	0.39	1.16	0.25	0.64
71	*Antiaris toxicoria*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
72	*Dendrocnide sinuata*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
73	*Diosypros paniculata*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
74	*Dipterocarpus indicus*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
75	*Flacourtia jangomas*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
76	*Haldina cordifolia*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
77	*Kingiodendron pinnatum*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
78	*Symplocos racemosa*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
79	*Turpania malabarica*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
80	*Vitex altissama*	2.00	1.72	9.30	0.26	1.16	0.25	0.51
81	*Bischofia javanica*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
82	*Bixa orellana*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
83	*Canarium strictum*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
84	*Celtis timorensis*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
85	*Chiolanthus mala-elengi*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
86	*Debrageasia longifolia*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
87	*Gomphandra coriaceae*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
88	*Gordonia obtusa*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
89	*Mallotus tetracoccus*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
90	*Memocylon umbellatum*	1.00	0.86	4.65	0.13	1.16	0.25	0.38

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
91	*Myristica fatua*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
92	*Poeciloneuron indicum*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
93	*Pterospermum diversifolium*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
94	*Pychotria nigra*	1.00	0.86	4.65	0.13	1.16	0.25	0.38
95	*Semercarpus anacardium*	1.00	0.86	4.65	0.13	1.16	0.25	0.38

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix III: IVI of tree seedlings of West Coast Tropical Evergreen Forest

S/No.	Name of species	AB	AB/F	D	RD	F	RF	IVI
1	*Diospyros candolleana*	1.33	0.09	2000.00	7.19	15.00	6.94	14.13
2	*Carallia brachiata*	1.59	0.17	1500.00	5.39	9.44	4.37	9.76
3	*Dysoxylum malabaricum*	1.87	0.22	1555.56	5.59	8.33	3.86	9.44
4	*Vateria indica*	1.29	0.14	1222.22	4.39	9.44	4.37	8.76
5	*Mesua ferrea*	1.13	0.13	1000.00	3.59	8.89	4.11	7.71
6	*Psydrax dicoccos*	1.62	0.22	1166.67	4.19	7.22	3.34	7.53
7	*Hopea parviflora*	1.20	0.14	1000.00	3.59	8.33	3.86	7.45
8	*Schleichera oleosa*	1.13	0.14	944.44	3.39	8.33	3.86	7.25
9	*Xanthophyllum arnottianum*	1.29	0.17	1000.00	3.59	7.78	3.60	7.19
10	*Diospyros buxifolia*	2.00	0.36	1111.11	3.99	5.56	2.57	6.56
11	*Cullenia exarillata*	1.33	0.20	888.89	3.19	6.67	3.08	6.28
12	*Holigarna arnottiana*	1.70	0.31	944.44	3.39	5.56	2.57	5.96
13	*Baccaurea courtallensis*	1.17	0.18	777.78	2.79	6.67	3.08	5.88
14	*Persea macrantha*	1.00	0.16	611.11	2.20	6.11	2.83	5.02
15	*Gluta travancorica*	1.20	0.22	666.67	2.40	5.56	2.57	4.97
16	*Symplocos cochinchinensis*	1.71	0.44	666.67	2.40	3.89	1.80	4.19
17	*Cinnamomum malabatrum*	1.14	0.29	444.44	1.60	3.89	1.80	3.40
18	*Anacolosa densiflora*	1.00	0.26	388.89	1.40	3.89	1.80	3.20
19	*Polyalthia fragrans*	1.00	0.26	388.89	1.40	3.89	1.80	3.20
20	*Syzygium mundagam*	1.00	0.26	388.89	1.40	3.89	1.80	3.20
21	*Otonephelium stipulaceum*	1.00	0.30	333.33	1.20	3.33	1.54	2.74
22	*Myristica dactylaides*	1.40	0.50	388.89	1.40	2.78	1.29	2.68

S/No.	Name of species	AB	AB/F	D	RD	F	RF	IVI
23	*Diosypros foliosa*	1.20	0.43	333.33	1.20	2.78	1.29	2.48
24	*Syzygium hemisphericum*	1.20	0.43	333.33	1.20	2.78	1.29	2.48
25	*Dipterocarpus bourdillonii*	1.00	0.36	277.78	1.00	2.78	1.29	2.28
26	*Knema attenuata*	1.00	0.36	277.78	1.00	2.78	1.29	2.28
27	*Atalantia racemosa*	1.50	0.68	333.33	1.20	2.22	1.03	2.23
28	*Aporosa cardiosperma*	1.25	0.56	277.78	1.00	2.22	1.03	2.03
29	*Croton malabaricus*	1.25	0.56	277.78	1.00	2.22	1.03	2.03
30	*Syzygium densiflorum*	1.25	0.56	277.78	1.00	2.22	1.03	2.03
31	*Syzygium cumini*	2.00	1.20	333.33	1.20	1.67	0.77	1.97
32	*Lophopetalum wightianum*	1.00	0.45	222.22	0.80	2.22	1.03	1.83
33	*Calophyllum polyanthum*	1.67	1.00	277.78	1.00	1.67	0.77	1.77
34	*Palaquium ellipticum*	1.67	1.00	277.78	1.00	1.67	0.77	1.77
35	*Litsea coriacea*	1.33	0.80	222.22	0.80	1.67	0.77	1.57
36	*Agrostistachys borneensis*	1.00	0.60	166.67	0.60	1.67	0.77	1.37
37	*Cinnamomum sulphuratum*	1.00	0.60	166.67	0.60	1.67	0.77	1.37
38	*Goniothalamus rhynchantherus*	1.00	0.60	166.67	0.60	1.67	0.77	1.37
39	*Nothapodytes nimmoniana*	1.00	0.60	166.67	0.60	1.67	0.77	1.37
40	*Dipterocarpus indicus*	2.00	1.80	222.22	0.80	1.11	0.51	1.31
41	*Ixora brachiata*	2.00	1.80	222.22	0.80	1.11	0.51	1.31
42	*Miliusa wightiana*	0.67	0.40	111.11	0.40	1.67	0.77	1.17
43	*Actinodaphne malabarica*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
44	*Ardisia rhomboidea*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
45	*Hopea racophloea*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
46	*Litsea wightiana*	1.00	0.90	111.11	0.40	1.11	0.51	0.91

S/No.	Name of species	AB	AB/F	D	RD	F	RF	IVI
47	*Macaranga peltata*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
48	*Mallotus philippensis*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
49	*Mallotus tetracoccus*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
50	*Mangifera indica*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
51	*Myristica fatua*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
52	*Myristica malabarica*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
53	*Poeciloneuron indicum*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
54	*Pongamia pinnnata*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
55	*Strombosia ceylanica*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
56	*Turpinia malabarica*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
57	*Xylopia parvifolia*	1.00	0.90	111.11	0.40	1.11	0.51	0.91
58	*Dimocarpus longan*	2.00	3.60	111.11	0.40	0.56	0.26	0.66
59	*Diosypros paniculata*	2.00	3.60	111.11	0.40	0.56	0.26	0.66
60	*Flacourtia jangomas*	2.00	3.60	111.11	0.40	0.56	0.26	0.66
61	*Hopea ponga*	2.00	3.60	111.11	0.40	0.56	0.26	0.66
62	*Hydnocarpus alpina*	2.00	3.60	111.11	0.40	0.56	0.26	0.66
63	*Aglaia periviridis*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
64	*Artocarpus hirsutus*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
65	*Bhesa indica*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
66	*Canarium strictum*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
67	*Celtis philippensis*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
68	*Debrageasia longifolia*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
69	*Debragesea longifolia*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
70	*Elaeocarpus munronii*	1.00	1.80	55.56	0.20	0.56	0.26	0.46

S/No.	Name of species	AB	AB/F	D	RD	F	RF	IVI
71	*Elaeocarpus serratus*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
72	*Garcinia gummi gutta*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
73	*Gomphandra coriaceae*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
74	*Gordonia obtusa*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
75	*Hydnocarpus pentandra*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
76	*Kingiodendron pinnatum*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
77	*Macaranga indica*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
78	*Maesa Indica*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
79	*Mastixia arborea*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
80	*Melia dubia*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
81	*Memocylon umbelatum*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
82	*Murraya paniculata*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
83	*Paracroton pendalus*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
84	*Pterospermum diversifolium*	1.00	1.80	55.56	0.20	0.56	0.26	0.46
85	*Vepris bilocularis*	1.00	1.80	55.56	0.20	0.56	0.26	0.46

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix IV. IVI of different species in West Coast Tropical Semi-evergreen

S/No.	Name of Species	AB	AB/F	D	RD	Fs	RFs	BA	RBAs	IVI
1	*Baccaurea courtallensis*	4.33	0.08	59.09	6.46	54.55	4.03	1.22	0.29	10.78
2	*Hopea parviflora*	3.29	0.08	35.91	3.93	43.64	3.22	12.09	2.88	10.03
3	*Xanthophyllum arnottianum*	6.63	0.19	57.27	6.26	34.55	2.55	2.87	0.68	9.50
4	*Kingiodendron pinnatum*	1.71	0.04	16.36	1.79	38.18	2.82	10.37	2.47	7.08
5	*Schleichera oleosa*	2.04	0.04	25.00	2.73	49.09	3.62	2.37	0.57	6.92
6	*Dipterocarpus indicus*	1.25	0.06	6.82	0.75	21.82	1.61	18.00	4.29	6.64
7	*Stereospermum colais*	3.00	0.08	28.64	3.13	38.18	2.82	2.46	0.58	6.53
8	*Dysoxylum malabaricum*	2.56	0.08	20.91	2.29	32.73	2.42	5.35	1.27	5.98
9	*Polyalthia fragrans*	2.53	0.07	21.82	2.39	34.55	2.55	4.10	0.98	5.91
10	*Tetrameles nudiflora*	1.46	0.06	8.64	0.94	23.64	1.74	12.82	3.05	5.74
11	*Bombax ceiba*	1.00	0.11	2.27	0.25	9.09	0.67	20.16	4.80	5.72
12	*Aporusa cardiosperma*	9.33	0.57	38.18	4.17	16.36	1.21	0.94	0.22	5.61
13	*Artocarpus hirsutus*	1.50	0.08	6.82	0.75	18.18	1.34	14.33	3.41	5.50
14	*Cinnamomum malabatrum*	2.78	0.08	22.73	2.49	32.73	2.42	1.59	0.38	5.28
15	*Diospyros buxiflora*	3.21	0.13	20.45	2.24	25.45	1.88	4.52	1.08	5.19
16	*Sapindus trifoliata*	0.75	0.10	1.36	0.15	7.27	0.54	18.70	4.45	5.14
17	*Psydax dioccos*	3.44	0.12	25.00	2.73	29.09	2.15	0.70	0.17	5.05
18	*Diospyros foliosa*	3.40	0.12	23.18	2.53	27.27	2.01	1.21	0.29	4.84
19	*Lophopetalum wightianum*	2.25	0.15	8.18	0.89	14.55	1.07	11.80	2.81	4.78
20	*Diospyros paniculata*	3.85	0.16	22.73	2.49	23.64	1.74	2.09	0.50	4.73
21	*Mangifera indica*	1.33	0.24	1.82	0.20	5.45	0.40	16.44	3.91	4.52
22	*Canarium strictum*	1.71	0.06	13.18	1.44	30.91	2.28	3.25	0.77	4.50
23	*Vitex altissma*	2.07	0.08	13.18	1.44	25.45	1.88	4.91	1.17	4.49

S/No.	Name of Species	AB	AB/F	D	RD	Fs	RFs	BA	RBAs	IVI
24	*Vateria indica*	1.27	0.05	8.64	0.94	27.27	2.01	6.30	1.50	4.46
25	*Terminalia bellirica*	3.55	0.18	17.73	1.94	20.00	1.48	4.23	1.01	4.42
26	*Olea dioica*	2.85	0.12	16.82	1.84	23.64	1.74	2.20	0.52	4.11
27	*Antiaris toxicaria*	1.50	0.21	2.73	0.30	7.27	0.54	13.72	3.27	4.10
28	*Mesua ferrea*	1.67	0.06	11.36	1.24	27.27	2.01	2.93	0.70	3.95
29	*Ixora brachiata*	6.50	0.45	23.64	2.58	14.55	1.07	0.88	0.21	3.87
30	*Flacourtia montana*	3.25	0.15	17.73	1.94	21.82	1.61	1.32	0.31	3.86
31	*Tabernaemontana alternifolia*	3.82	0.19	19.09	2.09	20.00	1.48	0.51	0.12	3.69
32	*Hydnocarpus pentandra*	1.92	0.09	10.45	1.14	21.82	1.61	3.24	0.77	3.53
33	*Bischofia javanica*	2.36	0.12	11.82	1.29	20.00	1.48	2.92	0.69	3.46
34	*Pajanelia longifolia*	3.63	0.25	13.18	1.44	14.55	1.07	3.57	0.85	3.37
35	*Anacolosa densiflora*	1.55	0.08	7.73	0.84	20.00	1.48	4.06	0.97	3.29
36	*Xylopia parviflora*	1.75	0.24	3.18	0.35	7.27	0.54	9.21	2.19	3.08
37	*Dipterocarpus bourdillonii*	2.00	1.10	0.91	0.10	1.82	0.13	11.65	2.77	3.01
38	*Sterculia guttata*	2.30	0.13	10.45	1.14	18.18	1.34	2.11	0.50	2.99
39	*Pterygota alata*	1.75	0.24	3.18	0.35	7.27	0.54	8.58	2.04	2.93
40	*Palaquium ellipticum*	3.38	0.23	12.27	1.34	14.55	1.07	2.12	0.51	2.92
41	*Anthocephalus cadamba*	1.00	0.55	0.45	0.05	1.82	0.13	11.46	2.73	2.91
42	*Haldina cordifolia*	1.50	0.41	1.36	0.15	3.64	0.27	10.40	2.48	2.89
43	*Lannea coromandelica*	1.29	0.10	4.09	0.45	12.73	0.94	6.32	1.50	2.89
44	*Mallotus philippensis*	2.40	0.13	10.91	1.19	18.18	1.34	1.31	0.31	2.85
45	*Calophyllum polyanthum*	2.00	0.11	9.09	0.99	18.18	1.34	1.55	0.37	2.71
46	*Mitragyna parviflora*	2.50	0.23	6.82	0.75	10.91	0.81	4.83	1.15	2.70
47	*Syzygium hemisphericum*	1.00	0.28	0.91	0.10	3.64	0.27	9.63	2.29	2.66
48	*Memecylon umbellatum*	3.38	0.23	12.27	1.34	14.55	1.07	0.88	0.21	2.62

S/No.	Name of Species	AB	AB/F	D	RD	Fs	RFs	BA	RBAs	IVI
49	*Grewia tiliifolia*	1.50	0.41	1.36	0.15	3.64	0.27	9.05	2.16	2.57
50	*Syzygium gardneri*	1.33	0.24	1.82	0.20	5.45	0.40	8.28	1.97	2.57
51	*Alstonia scholaris*	1.86	0.15	5.91	0.65	12.73	0.94	4.01	0.96	2.54
52	*Holigarna arnottiana*	2.00	0.14	7.27	0.80	14.55	1.07	2.78	0.66	2.53
53	*Macaranga peltata*	1.60	0.09	7.27	0.80	18.18	1.34	1.54	0.37	2.50
54	*Glochidion zeylanicum*	2.63	0.18	9.55	1.04	14.55	1.07	1.41	0.34	2.45
55	*Strombosia ceylanica*	2.29	0.18	7.27	0.80	12.73	0.94	2.78	0.66	2.40
56	*Terminalia paniculata*	2.00	0.22	4.55	0.50	9.09	0.67	5.05	1.20	2.37
57	*Syzygium cumini*	1.86	0.15	5.91	0.65	12.73	0.94	2.86	0.68	2.27
58	*Myristica dactylaides*	3.00	0.55	4.09	0.45	5.45	0.40	5.94	1.42	2.27
59	*Otonephelium stipulaceum*	1.75	0.12	6.36	0.70	14.55	1.07	2.02	0.48	2.25
60	*Melia dubia*	2.40	0.26	5.45	0.60	9.09	0.67	3.60	0.86	2.12
61	*Dimocarpus longan*	3.00	0.33	6.82	0.75	9.09	0.67	2.97	0.71	2.12
62	*Diospyros montana*	3.17	0.29	8.64	0.94	10.91	0.81	1.54	0.37	2.12
63	*Lagerstreomia microcarpa*	2.75	0.38	5.00	0.55	7.27	0.54	4.05	0.96	2.05
64	*Carallia brachiata*	2.83	0.26	7.73	0.84	10.91	0.81	1.66	0.39	2.05
65	*Poeciloneuron indicum*	2.50	0.69	2.27	0.25	3.64	0.27	6.19	1.47	1.99
66	*Strychnos-nux-vomica*	3.00	0.33	6.82	0.75	9.09	0.67	2.04	0.49	1.90
67	*Knema atttenuata*	2.25	0.31	4.09	0.45	7.27	0.54	3.82	0.91	1.89
68	*Mastixia arborea*	2.75	0.38	5.00	0.55	7.27	0.54	3.05	0.73	1.81
69	*Pterospermum diversifolium*	4.33	0.79	5.91	0.65	5.45	0.40	3.09	0.74	1.78
70	*Elaeocarpus serratus*	2.33	0.21	6.36	0.70	10.91	0.81	1.15	0.27	1.78
71	*Dillenia pentagyna*	1.33	0.24	1.82	0.20	5.45	0.40	4.53	1.08	1.68
72	*Atalantia racemosa*	3.60	0.40	8.18	0.89	9.09	0.67	0.36	0.09	1.65
73	*Melicope-lunu-ankeda*	4.25	0.58	7.73	0.84	7.27	0.54	0.71	0.17	1.55

S/No.	Name of Species	AB	AB/F	D	RD	Fs	RFs	BA	RBAs	IVI
74	*Ficus drupacea pubescens*	1.00	0.14	1.82	0.20	7.27	0.54	3.41	0.81	1.55
75	*Lagerstreomia speciosa*	2.00	0.28	3.64	0.40	7.27	0.54	2.46	0.59	1.52
76	*Myristica malabarica*	2.00	0.37	2.73	0.30	5.45	0.40	2.98	0.71	1.41
77	*Aglaia lawii*	2.50	0.34	4.55	0.50	7.27	0.54	1.07	0.26	1.29
78	*Artocarpus gomezianus*	2.00	1.10	0.91	0.10	1.82	0.13	4.18	1.00	1.23
79	*Gmelina arborea*	1.25	0.17	2.27	0.25	7.27	0.54	1.44	0.34	1.13
80	*Syzygium mundagom*	1.25	0.17	2.27	0.25	7.27	0.54	1.44	0.34	1.13
81	*Hopea panga*	3.33	0.61	4.55	0.50	5.45	0.40	0.91	0.22	1.12
82	*Persea macrantha*	3.50	0.96	3.18	0.35	3.64	0.27	2.01	0.48	1.10
83	*Chionanthus mala-elengi*	5.00	1.38	4.55	0.50	3.64	0.27	0.58	0.14	0.90
84	*Garcinia gummi-gutta*	1.67	0.31	2.27	0.25	5.45	0.40	1.04	0.25	0.90
85	*Litsea coriacea*	4.00	1.10	3.64	0.40	3.64	0.27	0.88	0.21	0.88
86	*Ostodes zeylancius*	2.00	1.10	0.91	0.10	1.82	0.13	2.54	0.60	0.84
87	*Cassia fistula*	1.00	0.18	1.36	0.15	5.45	0.40	1.11	0.26	0.82
88	*Actinodaphne malabarica*	2.50	0.69	2.27	0.25	3.64	0.27	1.25	0.30	0.81
89	*Agrostistachys borneensis*	2.00	1.10	0.91	0.10	1.82	0.13	2.15	0.51	0.75
90	*Croton malabaricus*	1.00	0.18	1.36	0.15	5.45	0.40	0.73	0.17	0.73
91	*Miliusa wightiana*	0.50	0.14	0.45	0.05	3.64	0.27	1.61	0.38	0.70
92	*Macaranga indica*	1.50	0.41	1.36	0.15	3.64	0.27	0.59	0.14	0.56
93	*Hydnocarpus alpina*	2.00	0.55	1.82	0.20	3.64	0.27	0.28	0.07	0.53
94	*Diospyros candolleana*	4.00	2.20	1.82	0.20	1.82	0.13	0.60	0.14	0.48
95	*Glochidion ellipticum*	1.00	0.28	0.91	0.10	3.64	0.27	0.35	0.08	0.45
96	*Buchanania lanceolata*	3.00	1.65	1.36	0.15	1.82	0.13	0.70	0.17	0.45
97	*Pongamia pinnata*	2.00	1.10	0.91	0.10	1.82	0.13	0.62	0.15	0.38
98	*Solenocarpus indicus*	1.00	0.55	0.45	0.05	1.82	0.13	0.81	0.19	0.38

S/No.	Name of Species	AB	AB/F	D	RD	Fs	RFs	BA	RBAs	IVI
99	*Celtis philippensis*	3.00	1.65	1.36	0.15	1.82	0.13	0.40	0.09	0.38
100	*Aporosa bourdillonii*	1.00	0.55	0.45	0.05	1.82	0.13	0.67	0.16	0.34
101	*Antidesma menasu*	2.00	1.10	0.91	0.10	1.82	0.13	0.35	0.08	0.32

(AB- Abundance ; Species density; RDs – Relative density of the species; Fs- Frequency of the species ; RFs- Relative frequency of the species; BAs- Basal area of the species ; RBA – Relative basal area of the species ; IVI- Importance value index of the species)

Appendix V: IVI of the tree saplings of West Coast Tropical Semi-evergreen

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Xanthophyllum arnottianum*	2.36	0.09	251.06	8.56	26.60	6.48	15.04
2	*Hopea parviflora*	2.39	0.10	234.04	7.98	24.47	5.96	13.94
3	*Cinnamomum malabatrum*	1.90	0.09	170.21	5.81	22.34	5.44	11.25
4	*Baccaurea courtallensis*	1.50	0.06	140.43	4.79	23.40	5.70	10.49
5	*Diospyros buxifolia*	1.56	0.09	106.38	3.63	17.02	4.15	7.77
6	*Anacolosa densiflora*	1.91	0.16	89.36	3.05	11.70	2.85	5.90
7	*Ixora brachiata*	1.36	0.12	63.83	2.18	11.70	2.85	5.03
8	*Mallotus philippensis*	1.50	0.14	63.83	2.18	10.64	2.59	4.77
9	*Aporosa cardiosperma*	2.25	0.26	76.60	2.61	8.51	2.07	4.69
10	*Diospyros paniculata*	2.00	0.27	59.57	2.03	7.45	1.81	3.85
11	*Dysoxylum malabaricum*	2.33	0.37	59.57	2.03	6.38	1.55	3.59
12	*Diospyros candolleana*	1.57	0.21	46.81	1.60	7.45	1.81	3.41
13	*Agrostistachys borneensis*	1.29	0.17	38.30	1.31	7.45	1.81	3.12
14	*Myristica dactyloides*	2.40	0.45	51.06	1.74	5.32	1.30	3.04
15	*Olea dioica*	2.40	0.45	51.06	1.74	5.32	1.30	3.04
16	*Tetrameles nudiflora*	1.67	0.26	42.55	1.45	6.38	1.55	3.01
17	*Hopea ponga*	2.20	0.41	46.81	1.60	5.32	1.30	2.89
18	*Mesua ferrea*	1.50	0.24	38.30	1.31	6.38	1.55	2.86
19	*Schleichera oleosa*	2.75	0.65	46.81	1.60	4.26	1.04	2.63
20	*Diospyros foliosa*	1.80	0.34	38.30	1.31	5.32	1.30	2.60
21	*Dipterocarpus bourdillonii*	1.80	0.34	38.30	1.31	5.32	1.30	2.60
22	*Elaeocarpus serratus*	1.80	0.34	38.30	1.31	5.32	1.30	2.60
23	*Kingiodendron pinnatum*	1.80	0.34	38.30	1.31	5.32	1.30	2.60

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
24	*Otonephelium stipulaceum*	1.80	0.34	38.30	1.31	5.32	1.30	2.60
25	*Pongamia pinnata*	1.17	0.18	29.79	1.02	6.38	1.55	2.57
26	*Stereospermum colais*	1.17	0.18	29.79	1.02	6.38	1.55	2.57
27	*Alstonia scholaris*	1.60	0.30	34.04	1.16	5.32	1.30	2.46
28	*Carallia brachiata*	2.25	0.53	38.30	1.31	4.26	1.04	2.34
29	*Dipterocarpus indicus*	2.25	0.53	38.30	1.31	4.26	1.04	2.34
30	*Dimocarpus longan*	2.00	0.47	34.04	1.16	4.26	1.04	2.20
31	*Vitex altissma*	2.00	0.47	34.04	1.16	4.26	1.04	2.20
32	*Litsea coriacea*	1.75	0.41	29.79	1.02	4.26	1.04	2.05
33	*Psydrax dicoccos*	1.75	0.41	29.79	1.02	4.26	1.04	2.05
34	*Vateria indica*	1.75	0.41	29.79	1.02	4.26	1.04	2.05
35	*Mangifera indica*	1.00	0.19	21.28	0.73	5.32	1.30	2.02
36	*Syzygium mundagom*	1.00	0.19	21.28	0.73	5.32	1.30	2.02
37	*Actinodaphne malabarica*	2.67	0.84	34.04	1.16	3.19	0.78	1.94
38	*Canarium strictum*	1.50	0.35	25.53	0.87	4.26	1.04	1.91
39	*Macaranga peltata*	2.33	0.73	29.79	1.02	3.19	0.78	1.79
40	*Tabernaemontana alternifolia*	2.33	0.73	29.79	1.02	3.19	0.78	1.79
41	*Diospyros montana*	1.25	0.29	21.28	0.73	4.26	1.04	1.76
42	*Persea macrantha*	1.25	0.29	21.28	0.73	4.26	1.04	1.76
43	*Artocarpus hirsutus*	2.00	0.63	25.53	0.87	3.19	0.78	1.65
44	*Holigarna arnottiana*	2.00	0.63	25.53	0.87	3.19	0.78	1.65
45	*Spondias pinnata*	2.00	0.63	25.53	0.87	3.19	0.78	1.65
46	*Antiaris toxicaria*	1.33	0.42	17.02	0.58	3.19	0.78	1.36
47	*Haldina cordifolia*	1.33	0.42	17.02	0.58	3.19	0.78	1.36
48	*Knema attenuata*	1.33	0.42	17.02	0.58	3.19	0.78	1.36

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
49	*Pajanelia longifolia*	1.33	0.42	17.02	0.58	3.19	0.78	1.36
50	*Palaquium ellipticum*	1.33	0.42	17.02	0.58	3.19	0.78	1.36
51	*Solenocarpus indicus*	1.33	0.42	17.02	0.58	3.19	0.78	1.36
52	*Lagerstreomia microcarpa*	2.50	1.18	21.28	0.73	2.13	0.52	1.24
53	*Atalantia racemosa*	1.00	0.31	12.77	0.44	3.19	0.78	1.21
54	*Strombosia ceylanica*	1.00	0.31	12.77	0.44	3.19	0.78	1.21
55	*Calophyllum polyanthum*	2.00	0.94	17.02	0.58	2.13	0.52	1.10
56	*Croton malabaricus*	2.00	0.94	17.02	0.58	2.13	0.52	1.10
57	*Lagerstroemia speciosa*	2.00	0.94	17.02	0.58	2.13	0.52	1.10
58	*Miliusa wightiana*	2.00	0.94	17.02	0.58	2.13	0.52	1.10
59	*Pterospermum diversifolium*	2.00	0.94	17.02	0.58	2.13	0.52	1.10
60	*Sterculia guttata*	2.00	0.94	17.02	0.58	2.13	0.52	1.10
61	*Hydnocarpus pentandra*	1.50	0.71	12.77	0.44	2.13	0.52	0.95
62	*Lophopetalum wightianum*	1.50	0.71	12.77	0.44	2.13	0.52	0.95
63	*Polyalthia fragrans*	1.50	0.71	12.77	0.44	2.13	0.52	0.95
64	*Syzygium cumini*	1.50	0.71	12.77	0.44	2.13	0.52	0.95
65	*Chionanthus mala-elengi*	1.00	0.47	8.51	0.29	2.13	0.52	0.81
66	*Dalbergia latifolia*	1.00	0.47	8.51	0.29	2.13	0.52	0.81
67	*Garcinia gumma gutta*	1.00	0.47	8.51	0.29	2.13	0.52	0.81
68	*Poeciloneuron inducum*	1.00	0.47	8.51	0.29	2.13	0.52	0.81
69	*Sageraea grandiflora*	3.00	2.82	12.77	0.44	1.06	0.26	0.69
70	*Aglaia barberi*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
71	*Bischofia javanica*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
72	*Cassia fistula*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
73	*Celtis philipensis*	2.00	1.88	8.51	0.29	1.06	0.26	0.55

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
74	*Dillenia pentagyna*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
75	*Flacourtia montana*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
76	*Humboldtia decurrens*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
77	*Sapindus trifoliata*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
78	*Terminalia bellirica*	2.00	1.88	8.51	0.29	1.06	0.26	0.55
79	*Drypetes venusta*	1.00	0.94	4.26	0.15	1.06	0.26	0.40
80	*Gmelina arborea*	1.00	0.94	4.26	0.15	1.06	0.26	0.40
81	*Hydnocarpus alpina*	1.00	0.94	4.26	0.15	1.06	0.26	0.40
82	*Pterygota alata*	1.00	0.94	4.26	0.15	1.06	0.26	0.40
83	*Grewia tilifolia*	1.00	0.94	4.26	0.15	1.06	0.26	0.40
84	*Leea indica*	1.00	0.94	4.26	0.15	1.06	0.26	0.40
85	*Anthocephalus cadamba*	1.00	0.94	4.26	0.15	1.06	0.26	0.40

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix VI. IVI of the tree seedlings of West Coast Tropical Semi-evergreen

S/No.	Names of the Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Cinnamomum malabatrum*	1.41	0.08	2440.48	9.45	17.26	8.58	18.03
2	*Hopea parviflora*	1.48	0.10	2202.38	8.53	14.88	7.40	15.92
3	*Xanthophyllum arnottianum*	1.43	0.11	1785.71	6.91	12.50	6.21	13.13
4	*Baccaurea courtallensis*	1.39	0.13	1488.10	5.76	10.71	5.33	11.09
5	*Diospyros buxiflora*	1.27	0.14	1130.95	4.38	8.93	4.44	8.82
6	*Ixora brachiata*	1.07	0.12	952.38	3.69	8.93	4.44	8.12
7	*Anacolosa densiflora*	1.60	0.27	952.38	3.69	5.95	2.96	6.65
8	*Aporosa cardiosperma*	2.17	0.61	773.81	3.00	3.57	1.78	4.77
9	*Schleichera oleosa*	1.00	0.21	476.19	1.84	4.76	2.37	4.21
10	*Tabernaemontana alternifolia*	1.00	0.21	476.19	1.84	4.76	2.37	4.21
11	*Hopea ponga*	1.14	0.27	476.19	1.84	4.17	2.07	3.91
12	*Dipterocarpus indicus*	1.00	0.24	416.67	1.61	4.17	2.07	3.68
13	*Vateria indica*	1.17	0.33	416.67	1.61	3.57	1.78	3.39
14	*Diospyros foliosa*	1.60	0.54	476.19	1.84	2.98	1.48	3.32
15	*Knema attenuata*	1.60	0.54	476.19	1.84	2.98	1.48	3.32
16	*Diospyros candolleana*	1.00	0.28	357.14	1.38	3.57	1.78	3.16
17	*Carallia brachiata*	1.40	0.47	416.67	1.61	2.98	1.48	3.09
18	*Myristica dactylaides*	1.40	0.47	416.67	1.61	2.98	1.48	3.09
19	*Dysoxylum malabaricum*	1.75	0.74	416.67	1.61	2.38	1.18	2.80
20	*Actinodaphne malabarica*	1.00	0.34	297.62	1.15	2.98	1.48	2.63
21	*Dipterocarpus bourdillonii*	1.00	0.34	297.62	1.15	2.98	1.48	2.63
22	*Mallotus philippensis*	1.00	0.34	297.62	1.15	2.98	1.48	2.63
23	*Mesua ferrea*	1.00	0.34	297.62	1.15	2.98	1.48	2.63

S/No.	Names of the Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
24	*Spondias pinnata*	1.00	0.34	297.62	1.15	2.98	1.48	2.63
25	*Strombosia ceylanica*	1.00	0.34	297.62	1.15	2.98	1.48	2.63
26	*Antiaris toxicaria*	1.50	0.63	357.14	1.38	2.38	1.18	2.57
27	*Bischofia javanica*	1.50	0.63	357.14	1.38	2.38	1.18	2.57
28	*Syzygium mundagom*	1.25	0.53	297.62	1.15	2.38	1.18	2.34
29	*Dimocarpus longan*	1.00	0.42	238.10	0.92	2.38	1.18	2.11
30	*Pterygota alata*	1.67	0.93	297.62	1.15	1.79	0.89	2.04
31	*Stereospermum colais*	1.67	0.93	297.62	1.15	1.79	0.89	2.04
32	*Artocarpus hirsutus*	1.33	0.75	238.10	0.92	1.79	0.89	1.81
33	*Canarium strictum*	1.33	0.75	238.10	0.92	1.79	0.89	1.81
34	*Dillenia pentagyna*	1.33	0.75	238.10	0.92	1.79	0.89	1.81
35	*Garcinia gummi-gutta*	1.33	0.75	238.10	0.92	1.79	0.89	1.81
36	*Pysdrax dicoccoss*	1.33	0.75	238.10	0.92	1.79	0.89	1.81
37	*Terminalia paniculata*	1.33	0.75	238.10	0.92	1.79	0.89	1.81
38	*Diospyros paniculata*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
39	*Kingiodendron pinnatum*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
40	*Olea dioica*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
41	*Otonephelium stipulatceum*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
42	*Palaquium ellipticum*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
43	*Poeciloneuron inducum*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
44	*Terminalia bellirica*	1.00	0.56	178.57	0.69	1.79	0.89	1.58
45	*Polyalthia fragrans*	2.00	1.68	238.10	0.92	1.19	0.59	1.51
46	*Flacaurtia montana*	1.50	1.26	178.57	0.69	1.19	0.59	1.28
47	*Macaranga peltata*	1.50	1.26	178.57	0.69	1.19	0.59	1.28
48	*Mangifera indica*	1.50	1.26	178.57	0.69	1.19	0.59	1.28

S/No.	Names of the Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
49	*Agrostistachachys longifolia*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
50	*Atalantia racemosa*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
51	*Calophyllum polyanthum*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
52	*Cassia fistula*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
53	*Elaeocarpus serratus*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
54	*Litsea coriacea*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
55	*Persea macrantha*	1.00	0.84	119.05	0.46	1.19	0.59	1.05
56	*Alstonia scholaris*	2.00	3.36	119.05	0.46	0.60	0.30	0.76
57	*Croton malabaricus*	2.00	3.36	119.05	0.46	0.60	0.30	0.76
58	*Syzygium cumini*	2.00	3.36	119.05	0.46	0.60	0.30	0.76
59	*Albizia odoratissima*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
60	*Chionanthus mala-elengi*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
61	*Dalbergia latifolia*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
62	*Diospyros montana*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
63	*Haldina cordifolia*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
64	*Holigarna arnottiana*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
65	*Hydnocarpus pentandra*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
66	*Macaranga indica*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
67	*Miliusa wightiana*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
68	*Pongamia pinnata*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
69	*Sterculia guttata*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
70	*Syzygium gardneri*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
71	*Tetrameles nudiflora*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
72	*Vitex altissma*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
73	*Grewia tilifolia*	1.00	1.68	59.52	0.23	0.60	0.30	0.53

S/No.	Names of the Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
74	*Leea indica*	1.00	1.68	59.52	0.23	0.60	0.30	0.53
75	*Semarcapus auriculata*	1.00	1.68	59.52	0.23	0.60	0.30	0.53

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix VII. IVI of tree species in the Southern Secondary Moist Deciduous Forest

S/No.	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	BA	RBA	IVI
1	*Terminalia paniculata*	7.68	0.10	141.45	16.13	73.68	7.07	9.44	3.47	26.67
2	*Aporosa cardiosperma*	9.85	0.14	168.42	19.20	68.42	6.57	0.84	0.31	26.08
3	*Olea dioica*	3.50	0.06	55.26	6.30	63.16	6.06	0.84	0.31	12.67
4	*Bombax ceiba*	1.22	0.05	7.24	0.83	23.68	2.27	20.70	7.60	10.70
5	*Tabernaemontana alternifolia*	4.65	0.10	51.97	5.93	44.74	4.29	0.72	0.26	10.48
6	*Bombox insigne*	1.00	0.38	0.66	0.08	2.63	0.25	25.78	9.47	9.80
7	*Careya arborea*	2.75	0.07	28.95	3.30	42.11	4.04	4.69	1.72	9.06
8	*Spondias pinnata*	1.00	0.38	0.66	0.08	2.63	0.25	22.99	8.45	8.77
9	*Schleichera oleosa*	1.94	0.04	21.71	2.48	44.74	4.29	1.98	0.73	7.50
10	*Dillenia pentagyna*	2.90	0.11	19.08	2.18	26.32	2.53	7.36	2.70	7.40
11	*Lagerstreomia microcarpa*	1.70	0.06	11.18	1.28	26.32	2.53	9.79	3.59	7.40
12	*Dalbergia sissoides.*	1.78	0.08	10.53	1.20	23.68	2.27	10.08	3.70	7.18
13	*Lagerstroemia speciosa*	1.60	0.12	5.26	0.60	13.16	1.26	13.50	4.96	6.82
14	*Terminalia elliptica*	1.80	0.14	5.92	0.68	13.16	1.26	12.81	4.70	6.64
15	*Pterocarpus marsupium*	2.43	0.13	11.18	1.28	18.42	1.77	9.73	3.57	6.62
16	*Macaranga peltata*	4.40	0.17	28.95	3.30	26.32	2.53	1.88	0.69	6.52
17	*Xanthophyllum arnottianum*	3.09	0.11	22.37	2.55	28.95	2.78	0.61	0.22	5.55
18	*Tetrameles nudiflora*	2.17	0.14	8.55	0.98	15.79	1.52	7.43	2.73	5.22
19	*Alstonia scholaris*	2.43	0.13	11.18	1.28	18.42	1.77	5.13	1.88	4.93
20	*Bridelia retusa*	3.13	0.15	16.45	1.88	21.05	2.02	2.19	0.80	4.70
21	*Terminalia bellirica*	1.40	0.11	4.61	0.53	13.16	1.26	7.59	2.79	4.58
22	*Mallotus philippensis*	5.00	0.38	16.45	1.88	13.16	1.26	3.64	1.34	4.48
23	*Pterygota alata*	2.25	0.21	5.92	0.68	10.53	1.01	7.29	2.68	4.36
24	*Phyllanthus emblica*	1.33	0.06	7.89	0.90	23.68	2.27	3.02	1.11	4.28
25	*Holarrhena pubescens*	5.33	0.34	21.05	2.40	15.79	1.52	0.94	0.34	4.26
26	*Strychnos-nux-vomica*	2.00	0.10	10.53	1.20	21.05	2.02	2.74	1.01	4.23

S/No.	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	BA	RBA	IVI
27	*Dalbergia latifolia*	1.75	0.17	4.61	0.53	10.53	1.01	7.12	2.62	4.15
28	*Haldina cordifolia*	2.17	0.14	8.55	0.98	15.79	1.52	4.47	1.64	4.13
29	*Grewia tiliifolia*	1.70	0.06	11.18	1.28	26.32	2.53	0.81	0.30	4.10
30	*Stereospermum colais*	1.56	0.07	9.21	1.05	23.68	2.27	1.92	0.71	4.03
31	*Buchanania lanzan*	2.00	0.13	7.89	0.90	15.79	1.52	4.37	1.60	4.02
32	*Macarangia indica*	4.40	0.33	14.47	1.65	13.16	1.26	2.29	0.84	3.75
33	*Wrightia tinctoria*	2.43	0.13	11.18	1.28	18.42	1.77	1.31	0.48	3.53
34	*Mitragyna parvifolia*	2.17	0.14	8.55	0.98	15.79	1.52	2.73	1.00	3.49
35	*Terminalia crenulata*	2.50	0.16	9.87	1.13	15.79	1.52	1.92	0.70	3.34
36	*Lannea coromandelica*	1.50	0.29	1.97	0.23	5.26	0.51	6.82	2.50	3.23
37	*Cinnomomum malabatrum*	2.00	0.11	9.21	1.05	18.42	1.77	1.09	0.40	3.22
38	*Mallotus tetracoccus*	4.20	0.32	13.82	1.58	13.16	1.26	0.93	0.34	3.18
39	*Sterculia guttata*	1.83	0.12	7.24	0.83	15.79	1.52	1.15	0.42	2.76
40	*Cassia fistula*	1.50	0.29	1.97	0.23	5.26	0.51	5.48	2.01	2.74
41	*Vitex altissima*	1.00	0.05	4.61	0.53	18.42	1.77	1.21	0.44	2.74
42	*Miliusa tomentosa*	1.25	0.12	3.29	0.38	10.53	1.01	3.65	1.34	2.73
43	*Tamarindus indica*	1.00	0.38	0.66	0.08	2.63	0.25	6.44	2.37	2.69
44	*Diospyros buxifolia*	1.20	0.09	3.95	0.45	13.16	1.26	2.04	0.75	2.46
45	*Hymenodictyon orixense*	1.40	0.11	4.61	0.53	13.16	1.26	1.75	0.64	2.43
46	*Ixora brachiata*	2.60	0.20	8.55	0.98	13.16	1.26	0.27	0.10	2.34
47	*Sterculia balanghas*	1.00	0.38	0.66	0.08	2.63	0.25	5.09	1.87	2.20
48	*Hydnocarcpus pentandra*	2.75	0.26	7.24	0.83	10.53	1.01	0.93	0.34	2.18
49	*Hymenodictyon obovatum*	4.33	0.55	8.55	0.98	7.89	0.76	0.62	0.23	1.96
50	*Chionanthus mala-elangi*	2.50	0.24	6.58	0.75	10.53	1.01	0.40	0.15	1.91
51	*Ailanthus triphysa*	1.00	0.38	0.66	0.08	2.63	0.25	3.90	1.43	1.76
52	*Wrightia arborea*	1.00	0.38	0.66	0.08	2.63	0.25	3.57	1.31	1.64
53	*Pongamia pinnata*	6.00	2.28	3.95	0.45	2.63	0.25	1.38	0.51	1.21

S/No.	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	BA	RBA	IVI
54	*Litsea coriacea*	3.00	0.57	3.95	0.45	5.26	0.51	0.55	0.20	1.16
55	*Naringi crenulata*	1.00	0.13	1.97	0.23	7.89	0.76	0.46	0.17	1.15
56	*Elaeocarpus tectorius*	1.00	0.19	1.32	0.15	5.26	0.51	1.17	0.43	1.08
57	*Melicope-lunu-ankenda*	3.00	1.14	1.97	0.23	2.63	0.25	1.40	0.52	0.99
58	*Elaeocarpus serratus*	1.00	0.38	0.66	0.08	2.63	0.25	1.27	0.47	0.80

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA- Relative basal area of the species; IVI- Importance value index of the species)

Appendix VIII. IVI of the tree saplings in the Southern Secondary Moist Deciduous Forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Aporosa cardiosperma*	1.61	0.03	316.88	13.38	49.35	14.13	27.50
2	*Olea dioica*	2.52	0.07	353.25	14.91	35.06	10.04	24.95
3	*Terminalia paniculata*	2.14	0.07	244.16	10.31	28.57	8.18	18.49
4	*Tabernaemontana alternifolia*	1.94	0.09	161.04	6.80	20.78	5.95	12.75
5	*Mallotus tetracoccus*	1.56	0.08	129.87	5.48	20.78	5.95	11.43
6	*Holarrhena pubescens*	1.77	0.10	119.48	5.04	16.88	4.83	9.88
7	*Careya arborea*	1.45	0.10	83.12	3.51	14.29	4.09	7.60
8	*Mallotus philippensis*	1.30	0.10	67.53	2.85	12.99	3.72	6.57
9	*Macaranga peltata*	1.44	0.12	67.53	2.85	11.69	3.35	6.20
10	*Schleichera oleosa*	1.44	0.12	67.53	2.85	11.69	3.35	6.20
11	*Cinnamomum malabatrum*	1.38	0.13	57.14	2.41	10.39	2.97	5.39
12	*Lagerstroemia speciosa*	1.29	0.14	46.75	1.97	9.09	2.60	4.58
13	*Stereospermum colais*	2.00	0.31	51.95	2.19	6.49	1.86	4.05
14	*Diospyros buxifolia*	1.33	0.17	41.56	1.75	7.79	2.23	3.98
15	*Ixora brachiata*	1.40	0.22	36.36	1.54	6.49	1.86	3.39
16	*Strychnos-nux-vomica*	1.40	0.22	36.36	1.54	6.49	1.86	3.39
17	*Xanthophyllum arnottianum*	2.00	0.39	41.56	1.75	5.19	1.49	3.24
18	*Terminalia bellirica*	1.75	0.34	36.36	1.54	5.19	1.49	3.02
19	*Phyllanthus emblica*	1.25	0.24	25.97	1.10	5.19	1.49	2.58
20	*Sterculia guttata*	1.00	0.19	20.78	0.88	5.19	1.49	2.36

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
21	*Chionanthus mala-elengi*	1.67	0.43	25.97	1.10	3.90	1.12	2.21
22	*Dalbergia sissoides*	1.67	0.43	25.97	1.10	3.90	1.12	2.21
23	*Bombax ceiba*	1.33	0.34	20.78	0.88	3.90	1.12	1.99
24	*Bridelia retusa*	1.33	0.34	20.78	0.88	3.90	1.12	1.99
25	*Mitragyna parviflora*	1.33	0.34	20.78	0.88	3.90	1.12	1.99
26	*Pterocarpus marsupium*	2.50	0.96	25.97	1.10	2.60	0.74	1.84
27	*Lagerstreomia microcarpa*	1.00	0.26	15.58	0.66	3.90	1.12	1.77
28	*Wrightia tinctoria*	1.00	0.26	15.58	0.66	3.90	1.12	1.77
29	*Pterygota alata*	2.00	0.77	20.78	0.88	2.60	0.74	1.62
30	*Lannea coromendelica*	1.50	0.58	15.58	0.66	2.60	0.74	1.40
31	*Terminalia crenulata*	1.50	0.58	15.58	0.66	2.60	0.74	1.40
32	*Terminalia elliptica*	1.50	0.58	15.58	0.66	2.60	0.74	1.40
33	*Walsura trifoliata*	1.50	0.58	15.58	0.66	2.60	0.74	1.40
34	*Vitex altissma*	4.00	3.08	20.78	0.88	1.30	0.37	1.25
35	*Dalbergia latifolia*	1.00	0.39	10.39	0.44	2.60	0.74	1.18
36	*Madhuca longifolia*	1.00	0.39	10.39	0.44	2.60	0.74	1.18
37	*Dillenia pentagyna*	3.00	2.31	15.58	0.66	1.30	0.37	1.03
38	*Haldina cordifolia*	2.00	1.54	10.39	0.44	1.30	0.37	0.81
39	*Macaranga indica*	2.00	1.54	10.39	0.44	1.30	0.37	0.81
40	*Pongamia pinnata*	2.00	1.54	10.39	0.44	1.30	0.37	0.81
41	*Buchanania lanzan*	1.00	0.77	5.19	0.22	1.30	0.37	0.59

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
42	*Dysoxylum malabaricum*	1.00	0.77	5.19	0.22	1.30	0.37	0.59
43	*Mangifera indica*	1.00	0.77	5.19	0.22	1.30	0.37	0.59
44	*Naringi crenulata*	1.00	0.77	5.19	0.22	1.30	0.37	0.59

(AB- Abundance; Species density; RDs –Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix IX. IVI of the dominant tree seedlings of southern secondary moist deciduous forest

S/No.	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	IVI
1	*Mallotus tetracoccus*	1.47	0.09	2393.16	12.54	16.24	10.38	22.92
2	*Tabernaemontana alternifolia*	1.35	0.09	1965.81	10.30	14.53	9.29	19.59
3	*Olea dioica*	1.11	0.07	1709.40	8.96	15.38	9.84	18.79
4	*Aporosa cardiosperma*	1.08	0.10	1196.58	6.27	11.11	7.10	13.37
5	*Terminalia paniculata*	1.36	0.15	1282.05	6.72	9.40	6.01	12.73
6	*Wrightia tinctoria*	2.00	0.29	1367.52	7.17	6.84	4.37	11.54
7	*Ixora brachiata*	1.22	0.16	940.17	4.93	7.69	4.92	9.84
8	*Careya arborea*	1.00	0.13	769.23	4.03	7.69	4.92	8.95
9	*Diospyros buxifolia*	1.00	0.15	683.76	3.58	6.84	4.37	7.95
10	*Schleichera oleosa*	1.29	0.21	769.23	4.03	5.98	3.83	7.86
11	*Mallotus philippensis*	1.00	0.17	598.29	3.14	5.98	3.83	6.96
12	*Cinnamomum malabatrum*	1.00	0.20	512.82	2.69	5.13	3.28	5.97
13	*Macaranga peltata*	1.00	0.20	512.82	2.69	5.13	3.28	5.97
14	*Pterocarpus marsupium*	1.75	0.51	598.29	3.14	3.42	2.19	5.32
15	*Xanthophyllum arnottianum*	1.00	0.23	427.35	2.24	4.27	2.73	4.97
16	*Holarrhena pubescens*	1.50	0.44	512.82	2.69	3.42	2.19	4.87
17	*Sterculia guttata*	1.50	0.44	512.82	2.69	3.42	2.19	4.87
18	*Strychnos-nux-vomica*	1.50	0.44	512.82	2.69	3.42	2.19	4.87
19	*Stereospermum colais*	1.67	0.65	427.35	2.24	2.56	1.64	3.88
20	*Bridelia retusa*	1.00	0.39	256.41	1.34	2.56	1.64	2.98
21	*Lagerstreomia microcarpa*	1.50	0.88	256.41	1.34	1.71	1.09	2.44
22	*Haldina cordifolia*	1.00	0.59	170.94	0.90	1.71	1.09	1.99
23	*Lagerstroemia speciosa*	1.00	0.59	170.94	0.90	1.71	1.09	1.99
24	*Cassia fistula*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
25	*Dalbergia latifolia*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
S/No.	**Name of Species**	**AB**	**AB/F**	**Ds**	**RD**	**Fs**	**RFs**	**IVI**

26	*Dalbergia sissoides*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
27	*Mangifera indica*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
28	*Morinda pubescens*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
29	*Phyllanthus emblica*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
30	*Pterygota alata*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
31	*Terminalia bellirica*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
32	*Vitex altissima*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
33	*Wrightia arborea*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
34	*Vitex pinnata*	1.00	1.17	85.47	0.45	0.85	0.55	0.99
35	*Madhuca longifolia*	1.00	1.17	85.47	0.45	0.85	0.55	0.99

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix X. IVI of tree species in Myristica Swamp Forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BAs	RBAs	IVI
1	*Myristica dactyloides*	5.00	0.05	222.22	19.42	100.00	10.26	816.04	34.11	63.78
2	*Myristica fatua*	5.42	0.05	240.74	21.04	100.00	10.26	180.71	7.55	38.85
3	*Knema attenuata*	3.50	0.04	129.63	11.33	83.33	8.55	128.95	5.39	25.26
4	*Vateria indica*	3.00	0.04	100.00	8.74	75.00	7.69	197.72	8.26	24.69
5	*Holigarna arnottiana*	2.00	0.06	29.63	2.59	33.33	3.42	266.78	11.15	17.16
6	*Hopea parviflora*	2.13	0.03	62.96	5.50	66.67	6.84	40.62	1.70	14.04
7	*Gymnacranthera farquhariana*	1.75	0.03	51.85	4.53	66.67	6.84	27.56	1.15	12.52
8	*Lophopetalum wightianum*	1.67	0.03	37.04	3.24	50.00	5.13	57.98	2.42	10.79
9	*Haldina cordifolia*	1.00	0.04	11.11	0.97	25.00	2.56	139.65	5.84	9.37
10	*Myristica malabarica*	2.50	0.08	37.04	3.24	33.33	3.42	46.49	1.94	8.60
11	*Xanthophyllum arnottianum*	1.25	0.04	18.52	1.62	33.33	3.42	75.52	3.16	8.19
12	*Baccaurea courtallensis*	1.40	0.03	25.93	2.27	41.67	4.27	1.76	0.07	6.61
13	*Lannea coromandolica*	1.00	0.12	3.70	0.32	8.33	0.85	97.53	4.08	5.25
14	*Mitraphora grandiflora*	2.50	0.15	18.52	1.62	16.67	1.71	39.07	1.63	4.96
15	*Cinnamomum malabatrum*	1.33	0.05	14.81	1.29	25.00	2.56	0.47	0.02	3.88
16	*Hydnocarpus pentandra*	1.00	0.06	7.41	0.65	16.67	1.71	31.93	1.33	3.69
17	*Aporosa bourdilloni*	2.00	0.24	7.41	0.65	8.33	0.85	52.23	2.18	3.68
18	*Buchanania axillaris*	2.00	0.24	7.41	0.65	8.33	0.85	46.66	1.95	3.45
19	*Dysoxylum macrocarpum*	1.00	0.06	7.41	0.65	16.67	1.71	25.13	1.05	3.41
20	*Mitragyna parviflora*	3.00	0.36	11.11	0.97	8.33	0.85	35.66	1.49	3.32
21	*Mesua ferrea*	1.00	0.06	7.41	0.65	16.67	1.71	22.21	0.93	3.29
22	*Diospyros paniculata*	1.50	0.09	11.11	0.97	16.67	1.71	9.63	0.40	3.08
23	*Garcinia gummi-gutta*	1.50	0.09	11.11	0.97	16.67	1.71	7.76	0.32	3.00
24	*Kingleodendron pinnatum*	1.00	0.06	7.41	0.65	16.67	1.71	8.95	0.37	2.73
25	*Mastixia arborea arborea*	1.00	0.06	7.41	0.65	16.67	1.71	7.70	0.32	2.68
26	*Humboltia vahliana*	1.00	0.06	7.41	0.65	16.67	1.71	2.48	0.10	2.46

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	BAs	RBAs	IVI
27	*Hopea malabarica*	3.00	0.36	11.11	0.97	8.33	0.85	12.55	0.52	2.35
28	*Gomphandra coriacea*	3.00	0.36	11.11	0.97	8.33	0.85	1.86	0.08	1.90
29	*Atlantia racemosa*	2.00	0.24	7.41	0.65	8.33	0.85	2.76	0.12	1.62
30	*Diospyros foliosa*	2.00	0.24	7.41	0.65	8.33	0.85	1.70	0.07	1.57
31	*Lagerstroemia reginae*	1.00	0.12	3.70	0.32	8.33	0.85	6.17	0.26	1.44
32	*Melicope lunu-ankenda*	1.00	0.12	3.70	0.32	8.33	0.85	0.20	0.01	1.19
33	*Aporosa cardiosperma*	1.00	0.12	3.70	0.32	8.33	0.85	0.16	0.01	1.18

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species ; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA – Relative basal area of the species; IVI- Importance value index of the species)

Appendix XI. IVI of the tree saplings of Myristica Swamp Forest

S/No.	Name of Specie	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Knema attenuata*	2.10	0.05	336.00	14.38	40.00	6.85	21.23
2	*Gymnacranthera farquhariana*	2.17	0.09	208.00	8.90	24.00	4.11	13.01
3	*Myristica dactyloides*	1.38	0.04	176.00	7.53	32.00	5.48	13.01
4	*Hopea parviflora*	2.20	0.11	176.00	7.53	20.00	3.42	10.96
5	*Myristica fatua*	2.20	0.11	176.00	7.53	20.00	3.42	10.96
6	*Myristica malabarica*	2.00	0.10	160.00	6.85	20.00	3.42	10.27
7	*Cinnamomum malabatrum*	1.00	0.04	112.00	4.79	28.00	4.79	9.59
8	*Hydnocarpus pentandra*	1.33	0.06	128.00	5.48	24.00	4.11	9.59
9	*Viteria indica*	1.40	0.07	112.00	4.79	20.00	3.42	8.22
10	*Diospyros buxifolia*	1.20	0.06	96.00	4.11	20.00	3.42	7.53
11	*Holigarna arnottiana*	1.75	0.11	112.00	4.79	16.00	2.74	7.53
12	*Baccaurea courtallensis*	1.50	0.09	96.00	4.11	16.00	2.74	6.85
13	*Syzygium travancoricum*	1.50	0.19	48.00	2.05	8.00	1.37	3.42
14	*Aporosa cardiosperma*	1.00	0.13	32.00	1.37	8.00	1.37	2.74
15	*Grewia serrulata*	1.00	0.13	32.00	1.37	8.00	1.37	2.74
16	*Ixora brachiata*	1.00	0.13	32.00	1.37	8.00	1.37	2.74
17	*Leea indica*	1.00	0.13	32.00	1.37	8.00	1.37	2.74
18	*Dysoxylum malabaricum*	2.00	0.50	32.00	1.37	4.00	0.68	2.05
19	*Glochidion zeylanicum*	2.00	0.50	32.00	1.37	4.00	0.68	2.05
20	*Mesua ferrea*	2.00	0.50	32.00	1.37	4.00	0.68	2.05
21	*Murayya paniculata*	2.00	0.50	32.00	1.37	4.00	0.68	2.05
22	*Strombosia ceylanica*	2.00	0.50	32.00	1.37	4.00	0.68	2.05
23	*Atlantia racemosa*	1.00	0.25	16.00	0.68	4.00	0.68	1.37
24	*Humboldtia vahliana*	1.00	0.25	16.00	0.68	4.00	0.68	1.37
S/No.	**Name of Species**	**AB**	**AB/F**	**Ds**	**RD**	**Fs**	**RFs**	**IVI**

25	*Mallotus philippensis*	1.00	0.25	16.00	0.68	4.00	0.68	1.37
26	*Olea dioica*	1.00	0.25	16.00	0.68	4.00	0.68	1.37
27	*Semarcarpus auriculata*	1.00	0.25	16.00	0.68	4.00	0.68	1.37
28	*Syzygium mundagam*	1.00	0.25	16.00	0.68	4.00	0.68	1.37
29	*Xanthaphyllum anottianum*	1.00	0.25	16.00	0.68	4.00	0.68	1.37

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix XII. IVI of the tree seedlings of Myristica Swamp Forest

S/No	Name of Species	AB	AB/F	Ds	RD	Fs	RFs	IVI
1	*Myristica dactyloides*	1.60	0.06	4000.00	15.84	25.00	13.70	29.54
2	*Cinnamomum malabatrum*	1.57	0.09	2750.00	10.89	17.50	9.59	20.48
3	*Knema attenuata*	1.43	0.08	2500.00	9.90	17.50	9.59	19.49
4	*Holigarna arnottiana*	1.50	0.15	1500.00	5.94	10.00	5.48	11.42
5	*Myristica fatua*	1.50	0.15	1500.00	5.94	10.00	5.48	11.42
6	*Vateria indica*	1.50	0.15	1500.00	5.94	10.00	5.48	11.42
7	*Diospyros buxifolia*	1.00	0.10	1000.00	3.96	10.00	5.48	9.44
8	*Hopea parviflora*	1.67	0.22	1250.00	4.95	7.50	4.11	9.06
9	*Baccaurea courtallensis*	1.33	0.18	1000.00	3.96	7.50	4.11	8.07
10	*Hydnocarpus pentandra*	1.33	0.18	1000.00	3.96	7.50	4.11	8.07
11	*Leea indica*	1.33	0.18	1000.00	3.96	7.50	4.11	8.07
12	*Gymnacranthera farquhariana*	1.50	0.30	750.00	2.97	5.00	2.74	5.71
13	*Myristica malabarica*	1.50	0.30	750.00	2.97	5.00	2.74	5.71
14	*Olea dioica*	1.50	0.30	750.00	2.97	5.00	2.74	5.71
15	*Grewia serrulata*	1.00	0.20	500.00	1.98	5.00	2.74	4.72
16	*Ixora brachiata*	1.00	0.20	500.00	1.98	5.00	2.74	4.72
17	*Strombosia ceylanica*	1.00	0.20	500.00	1.98	5.00	2.74	4.72
18	*Murayya paniculata*	2.00	0.80	500.00	1.98	2.50	1.37	3.35
19	*Aporosa cardiosperma*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
20	*Dysoxylum malabaricum*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
21	*Glochidion zeylanicum*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
22	*Mallotus philippensis*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
23	*Psychotra nigra*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
S/No.	**Name of Species**	**AB**	**AB/F**	**Ds**	**RD**	**Fs**	**RFs**	**IVI**

24	*Semarcarpus auriculata*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
25	*Syzygium travancoricum*	1.00	0.40	250.00	0.99	2.50	1.37	2.36
26	*Xanthaphyllum anottianum*	1.00	0.40	250.00	0.99	2.50	1.37	2.36

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix XIII. IVI of different tree species in the Tropical Hilltop Forest

S/No.	Name of Specie	AB	AB/F	Ds	RD	Fs	RF	BA	RBA	IVI
1	*Vernonia travancorica*	5.50	0.10	76.39	12.33	55.56	5.68	1.35	0.93	18.95
2	*Symplocos cochinchinensis*	4.22	0.08	52.78	8.52	50.00	5.11	2.06	1.42	15.05
3	*Elaeocarpus munronii*	3.22	0.06	40.28	6.50	50.00	5.11	2.53	1.74	13.36
4	*Gluta travancorica*	2.00	0.36	2.78	0.45	5.56	0.57	15.59	10.74	11.75
5	*Neolitsea scrobiculata*	3.17	0.10	26.39	4.26	33.33	3.41	3.58	2.46	10.13
6	*Ficus tsjahela*	1.00	0.18	1.39	0.22	5.56	0.57	12.04	8.29	9.08
7	*Bhesa indica*	1.80	0.06	12.50	2.02	27.78	2.84	6.05	4.17	9.02
8	*Garcinia travancorica*	1.83	0.06	15.28	2.47	33.33	3.41	4.34	2.99	8.87
9	*Litsea oleoides*	3.25	0.15	18.06	2.91	22.22	2.27	5.21	3.59	8.78
10	*Litsea floribunda*	3.00	0.09	25.00	4.04	33.33	3.41	1.38	0.95	8.39
11	*Calophyllum polyanthum*	2.50	0.23	6.94	1.12	11.11	1.14	8.80	6.06	8.32
12	*Poecilonueron indicus*	2.00	0.09	11.11	1.79	22.22	2.27	6.02	4.15	8.21
13	*Cinnamomum sulpharatum*	2.17	0.07	18.06	2.91	33.33	3.41	2.22	1.53	7.85
14	*Actinodaphne malabarica*	2.60	0.09	18.06	2.91	27.78	2.84	2.96	2.04	7.79
15	*Agrostistachys borneensis*	2.00	0.18	5.56	0.90	11.11	1.14	8.16	5.62	7.65
16	*Syzygium rubicundum*	2.80	0.10	19.44	3.14	27.78	2.84	2.20	1.52	7.50
17	*Eugenia discifera*	2.17	0.07	18.06	2.91	33.33	3.41	1.55	1.07	7.39
18	*Ardisia blatteri*	2.67	0.08	22.22	3.59	33.33	3.41	0.50	0.34	7.34
19	*Litsea keralana*	4.67	0.28	19.44	3.14	16.67	1.70	3.24	2.23	7.07
20	*Ardisia rhombifolia*	2.00	0.06	16.67	2.69	33.33	3.41	0.73	0.50	6.60
21	*Turpinia malabarica*	2.25	0.10	12.50	2.02	22.22	2.27	3.28	2.26	6.55
22	*Aglaia bourdillonii*	4.00	0.24	16.67	2.69	16.67	1.70	2.70	1.86	6.26
23	*Hydnocarpus alpina*	2.00	0.09	11.11	1.79	22.22	2.27	2.73	1.88	5.95
S/No.	**Name of Specie**	**AB**	**AB/F**	**Ds**	**RD**	**Fs**	**RF**	**BA**	**RBA**	**IVI**

24	*Gordonia obtusa*	1.25	0.06	6.94	1.12	22.22	2.27	3.54	2.43	5.83
25	*Actinodaphane companulata*	1.80	0.06	12.50	2.02	27.78	2.84	1.24	0.85	5.71
26	*Garcinia cowa*	2.33	0.14	9.72	1.57	16.67	1.70	3.07	2.12	5.39
27	*Mastixia arborea*	2.33	0.14	9.72	1.57	16.67	1.70	2.96	2.04	5.31
28	*Cinnamomum verum*	2.33	0.14	9.72	1.57	16.67	1.70	2.95	2.03	5.30
29	*Fagraea ceilanica*	2.25	0.10	12.50	2.02	22.22	2.27	1.40	0.97	5.26
30	*Dimocarpus longan*	1.00	0.18	1.39	0.22	5.56	0.57	6.44	4.44	5.23
31	*Melisoma pinnata*	2.33	0.14	9.72	1.57	16.67	1.70	2.76	1.90	5.17
32	*Garcinia imbertii*	2.00	0.12	8.33	1.35	16.67	1.70	2.71	1.87	4.92
33	*Maesa indica*	2.00	0.09	11.11	1.79	22.22	2.27	0.90	0.62	4.69
34	*Syzygium densiflorum*	2.00	0.12	8.33	1.35	16.67	1.70	2.21	1.52	4.57
35	*Syzygium caryophyllum*	2.00	0.09	11.11	1.79	22.22	2.27	0.69	0.48	4.54
36	*Goniothalamus wighii*	1.50	0.07	8.33	1.35	22.22	2.27	0.66	0.45	4.07
37	*Naringi crenulata*	1.50	0.07	8.33	1.35	22.22	2.27	0.57	0.39	4.01
38	*Goniothalamus rhynchantherus*	1.00	0.05	5.56	0.90	22.22	2.27	0.79	0.54	3.71
39	*Cinnomomum perrottetti*	1.33	0.08	5.56	0.90	16.67	1.70	1.49	1.02	3.63
40	*Celtis timorensis*	1.00	0.18	1.39	0.22	5.56	0.57	3.57	2.46	3.25
41	*Miliusa wightiana*	1.00	0.18	1.39	0.22	5.56	0.57	3.36	2.31	3.11
42	*Gomphondra coriaceae*	1.50	0.14	4.17	0.67	11.11	1.14	1.81	1.24	3.05
43	*Octotropis travancorica*	1.50	0.14	4.17	0.67	11.11	1.14	1.32	0.91	2.71
44	*Chionanthus mala-elengi*	1.00	0.09	2.78	0.45	11.11	1.14	1.58	1.08	2.67

(AB- Abundance; Species density; RDs– Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; BAs- Basal area of the species; RBA– Relative basal area of the species; IVI**-** Importance value index of the species)

Appendix XIV. IVI of the tree saplings of Tropical Hilltop Forest

S/No.	Name of Species	AB	AB/F	D	RDs	Fs	RFs	IVI
1	*Cinnamomum sulpharatum*	3.11	0.11	339.39	12.12	27.27	7.89	20.02
2	*Litsea floribonda*	2.33	0.09	254.55	9.09	27.27	7.89	16.99
3	*Ardisia rhomboidea*	2.17	0.12	157.58	5.63	18.18	5.26	10.89
4	*Actinodaphne malabarica*	1.83	0.10	133.33	4.76	18.18	5.26	10.03
5	*Elaeocarpus munronii*	1.67	0.09	121.21	4.33	18.18	5.26	9.59
6	*Caseara macrocarpa*	3.00	0.25	145.45	5.19	12.12	3.51	8.70
7	*Symplocos cochinchinensis*	1.80	0.12	109.09	3.90	15.15	4.39	8.28
8	*Litsea keralana*	2.75	0.23	133.33	4.76	12.12	3.51	8.27
9	*Vernonia travancorica*	1.40	0.09	84.85	3.03	15.15	4.39	7.42
10	*Litsea oleoides*	2.25	0.19	109.09	3.90	12.12	3.51	7.40
11	*Eugenia discifera*	2.00	0.17	96.97	3.46	12.12	3.51	6.97
12	*Syzygium densiflorum*	2.67	0.29	96.97	3.46	9.09	2.63	6.09
13	*Neolitsea scrobiculata*	1.25	0.10	60.61	2.16	12.12	3.51	5.67
14	*Actinodaphne campunulata*	2.33	0.26	84.85	3.03	9.09	2.63	5.66
15	*Fagraea ceilanica*	2.00	0.22	72.73	2.60	9.09	2.63	5.23
16	*Gomphondra coriaceae*	2.00	0.22	72.73	2.60	9.09	2.63	5.23
17	*Meliosma pinnata*	2.00	0.22	72.73	2.60	9.09	2.63	5.23
18	*Bhesa indica*	1.67	0.18	60.61	2.16	9.09	2.63	4.80
19	*Goniothalamus wighii*	1.33	0.15	48.48	1.73	9.09	2.63	4.36
20	*Mastixia arborea*	1.33	0.15	48.48	1.73	9.09	2.63	4.36
21	*Naringi crenulata*	3.00	0.50	72.73	2.60	6.06	1.75	4.35
22	*Turpinia malabarica*	2.50	0.41	60.61	2.16	6.06	1.75	3.92

S/No.	Name of Species	AB	AB/F	D	RDs	Fs	RFs	IVI
23	*Cinnamomum verum*	2.00	0.33	48.48	1.73	6.06	1.75	3.49
24	*Garcinia travancorica*	2.00	0.33	48.48	1.73	6.06	1.75	3.49
25	*Maesa indica*	2.00	0.33	48.48	1.73	6.06	1.75	3.49
26	*Aglaia bourdillonii*	1.50	0.25	36.36	1.30	6.06	1.75	3.05
28	*Hydnocarpus alpina*	1.50	0.25	36.36	1.30	6.06	1.75	3.05
29	*Garcinia cowa*	1.00	0.17	24.24	0.87	6.06	1.75	2.62
30	*Calophyllum polyanthum*	2.00	0.66	24.24	0.87	3.03	0.88	1.74
31	*Garcinia imbertii*	2.00	0.66	24.24	0.87	3.03	0.88	1.74
32	*Ardisia blatteri*	1.00	0.33	12.12	0.43	3.03	0.88	1.31
33	*Eugenia bracteata*	1.00	0.33	12.12	0.43	3.03	0.88	1.31
34	*Garcinia rubroechinata*	1.00	0.33	12.12	0.43	3.03	0.88	1.31
35	*Meiogyne ramorowi*	1.00	0.33	12.12	0.43	3.03	0.88	1.31
36	*Paracroton pendulus*	1.00	0.33	12.12	0.43	3.03	0.88	1.31
37	*Poecilonueron indicus*	1.00	0.33	12.12	0.43	3.03	0.88	1.31

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix XV. IVI of tree seedlings of Tropical Hilltop Forest

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
1	*Litsea floribunda*	1.33	0.09	1904.76	8.99	14.29	8.45	17.44
2	*Ardisia rhomboidea*	1.80	0.15	2142.86	10.11	11.90	7.04	17.16
3	*Cinnamomum sulpharatum*	1.60	0.13	1904.76	8.99	11.90	7.04	16.03
4	*Actinodaphne malabarica*	1.50	0.16	1428.57	6.74	9.52	5.63	12.38
5	*Syzygium densiflorum*	1.50	0.16	1428.57	6.74	9.52	5.63	12.38
6	*Elaeocarpus munronii*	1.25	0.13	1190.48	5.62	9.52	5.63	11.25
7	*Litsea oleoides*	1.00	0.11	952.38	4.49	9.52	5.63	10.13
8	*Symplocos cochinchinensis*	1.00	0.11	952.38	4.49	9.52	5.63	10.13
9	*Vernonia travancorica*	1.00	0.11	952.38	4.49	9.52	5.63	10.13
10	*Actinodaphne campunulata*	1.00	0.14	714.29	3.37	7.14	4.23	7.60
11	*Cinnomumum perrottetti*	2.00	0.42	952.38	4.49	4.76	2.82	7.31
12	*Hydnocarpus alpina*	1.50	0.32	714.29	3.37	4.76	2.82	6.19
13	*Maesa indica*	1.50	0.32	714.29	3.37	4.76	2.82	6.19
14	*Bhesa indica*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
15	*Calophyllum polyanthum*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
16	*Fagraea ceilanica*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
17	*Garcinia cowa*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
18	*Litsea keralana*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
19	*Nothopodytes nimmoniana*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
20	*Octotropis travancorica*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
21	*Psydrax spp*	1.00	0.21	476.19	2.25	4.76	2.82	5.06
22	*Aglaia bourdillonii*	1.00	0.42	238.10	1.12	2.38	1.41	2.53
23	*Cinnamomum verum*	1.00	0.42	238.10	1.12	2.38	1.41	2.53
24	*Eugenia discifera*	1.00	0.42	238.10	1.12	2.38	1.41	2.53
25	*Garcinia travancorica*	1.00	0.42	238.10	1.12	2.38	1.41	2.53

S/No.	Name of Species	AB	AB/F	Ds	RDs	Fs	RFs	IVI
26	*Mastixia arborea*	1.00	0.42	238.10	1.12	2.38	1.41	2.53
27	*Neolitsea scrobiculata*	1.00	0.42	238.10	1.12	2.38	1.41	2.53

(AB- Abundance; Species density; RDs – Relative density of the species; Fs- Frequency of the species; RFs- Relative frequency of the species; IVI- Importance value index of the species)

Appendix XVII: Details of tree species recorded in West Coast Tropical Evergreen Forest (WCTE)

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
1	*Actinodaphne malabarica* Balak.	Lauraceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
2	*Aglaia barberi*	Meliaceae	LC	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
3	*Aglaia malabarica*	Meliaceae	CE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
4	*Aglaia simplicifolia* (Bedd.) Hams	Meliaceae	LC	Southern Western Ghats	Ramesh and Pascal, 1997
5	*Agrostistachys borneensis* Becc.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
6	*Anacolosa densiflora* Bedd.	Olacaceae	CE	Southern Western Ghats	Rao *et al*., 2019
7	*Antiaris toxicaria*	Moraceae	LC	Not Endemic	Rao *et al*., 2019
8	*Aporosa cardiosperma* (Gaertn.) Merr.	Euphorbiaceae	VU	Not Endemic	Rao *et al*., 2019
9	*Ardisia rhomboidea* Wight	Myrsinaceae	NE	Southern Western Ghats	Rao *et al*., 2019
10	*Artocarpus hirsutus* Lamk.	Moraceae	LC	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
11	*Atalantia racemosa* Wight & Arn.var. racemosa	Rutaceae	NE	Not Endemic	Rao *et al*., 2019
12	*Baccaurea courtallensis* (Wight) Muell. Arg.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
13	*Bhesa indica* (Bedd.) Ding Hou	Celastraceae	NE	Not Endemic	Rao *et al*., 2019
14	*Bischofia javanica* Blume	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
15	*Bixa orellana*	Bixaceae	NE	Not Endemic	Rao *et al*., 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
16	*Calophyllum polyanthum* Wall.ex Choisy	Clusiaceae	NE	Not Endemic	Rao *et al.,* 2019
17	*Canarium strictum* Roxb.	Burseraceae	NE	Not Endemic	Rao *et al*., 2019
18	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	NE	Not Endemic	Rao et al., 2019
19	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	NE	Not Endemic	Rao *et al*., 2019
20	*Celtis timorensis* Span.	Ulmaceae	LC	Not Endemic	Rao *et al*., 2019
21	*Celtis philippensis* Wightii	Ulmaceae	LC	Not Endemic	Rao *et al*., 2019
22	*Chionanthus mala-elongi* (Dennst.) P.S. Green	Oleaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et* a*l.,* 2019
23	*Cinnamomum malabatrum* (Burm.f.) Blume	Lauraceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
24	*Cinnamomum sulphuratum* Ness.	Lauraceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
25	*Cinnamomum wightii* Meisn.	Lauraceae	EN	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
26	*Croton malabaricus* Bedd.	Euphorbiaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
27	*Cullenia exarillata* Robyns	Bombacaceae	VU	Western Ghats	Rao *et al*., 2019
28	*Dalbergia lanceolaria* L.f.	Fabaceae	LC	Not Endemic	Rao *et al.,* 2019
29	*Dendrocnide sinuata* (Blume) chew	Urticaceae	NE	Not Endemic	Rao *et al*., 2019
30	*Dillenia pentagyna* Roxb.	Dilleniaceae	NE	Not Endemic	Rao *et al*., 2019
31	*Dimocarpus longan* Lour.	Sapindaceae	NT	Not Endemic	Rao *et al*., 2019
32	*Diospyros candolleana* Wight	Ebenaceae	VU	Western Ghats	Ramesh and Pascal, 1997
33	*Diospyros foliosa Wall.ex A.DC.*	Ebenaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao et al., 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
34	*Diosypros buxifolia (Blume) Hiern*	Ebenaceae	NE	Not Endemic	Rao et al., 2019
35	*Diosypros paniculata* Dalz.	Ebenaceae	VU	Western Ghats	Ramesh and Pascal, 1997
36	*Dipterocarpus bourdillonii* Brand.	Dipterocarpaceae	EN	Western Ghats	Ramesh and Pascal, 1997
37	*Dipterocarpus indicus* Bedd.	Dipterocarpaceae	EN	Western Ghats	Ramesh and Pascal, 1997
38	*Dysoxylum malabaricum* Bedd.ex. C. DC.	Meliaceae	EN	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
39	*Ehretia canarensis* Miq.	Boraginaceae	NE	Not Endemic	Rao *et al*., 2019
40	*Elaeocarpus munronii* (Wight) Mast.	Eleocarpaceae	NT	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
41	*Elaeocarpus serratus* L.	Eleocarpaceae	NE	Not Endemic	Rao *et al.,* 2019
42	*Erythrina variegata* L.	Fabaceae	LC	Not Endemic	Rao *et al*., 2019
43	*Eugenia bracheata* (Willd.) Roxb.ex D.C	Myrtaceae	NE	Not Endemic	Rao *et al*., 2019
44	*Ficus dalhousiae* Miq.	Moraceae	NE	Not Endemic	Rao *et al*., 2019
45	*Ficus tsjahela*	Moraceae	NE	Not Endemic	Rao *et al*., 2019
46	*Flacourtia jangomas* (Lour.) Raeusch	Flacoutiaceae	NE	Western Ghats	Ramesh and Pascal, 1997
47	*Garcinia cowa* Roxb.ex DC.	Clusiaceae	NE	Not Endemic	Rao *et al*., 2019
48	*Garcinia gummi-gutta*	Clusiaceae	LC	Not Endemic	Rao *et al.,* 2019
49	*Garcinia morella* (Gaertn.) Desr.	Clusiaceae	NE	Not Endemic	Rao *et al*., 2019
50	*Garcinia travancorica* Bedd.	Clusiaceae	VU	Southern Western Ghats	Ramesh and Pascal, 1997
51	*Garcinia xanthochymus* Hook.f.	Clusiaceae	NE	Not Endemic	Rao *et al*., 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
52	*Glochidion zeylanicum*	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
53	*Gluta travancorica* Bedd.	Anacardiaceae	VU	Southern Western Ghats	Ramesh and Pascal, 1997
54	*Gomphandra coriacea* Wight	Icacinaceae	NE	Not Endemic	Rao *et al*., 2019
55	*Goniothalamus rhynchantherus* Dunn	Annonaceae	EN	Southern Western Ghats	Ramesh and Pascal., 1997
56	*Gordonia obtusa* Wall.	Theaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
57	*Haldina cordifolia* (Roxb.) Ridsd.	Rubiaceae	NE	Not Endemic	Rao *et al*., 2019
58	*Holigarna arnottiana* Hook. F.	Anacardiaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997
59	*Hopea malabarica*	Dipterocarpaceae	EN	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
60	*Hopea parviflora* Bedd.	Dipterocarpaceae	EN	Southern Western Ghats	Ramesh and Pascal, 1997
61	*Hopea ponga* (Dennst.) Mabber.	Dipterocarpaceae	EN	Western Ghats	Rao *et al*., 2019
62	*Humboldtia deccurrens* Bedd.ex Oliv.	Caesalpiniaceae	LC	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
63	*Hydnocarpus alpina* Wight	Achariaceae	NE	Not Endemic	Rao *et al*., 2019
64	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Flacoutiaceae	VU	Western Ghats	Rao et al., 2019
65	*Ixora brachiata* Roxb.ex DC.	Rubiaceae	NE	Not Endemic	Rao *et al.,* 2019
66	*Kingiodendron pinnatum* (Roxb. ex DC.)	Fabaceae	EN	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
67	*Knema attenuata* Warb.	Myristicaceae	LC	Western Ghats	Rao et al., 2019
68	*Lagerstroemia microcarpa* Wight	Lythraceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
69	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	NE	Not Endemic	Rao *et al*., 2019
70	*Litsea coriacea* (Heyne ex Wall.) Hook. F.	Lauraceae	NE	Western Ghats	Ramesh and Pascal, 1997
71	*Litsea oleoides* (Meissn.) Hook. f.	Lauraceae	NF	Southern Western Ghats	Rao *et al*., 2019
72	*Litsea wightiana* Hook. f.	Lauraceae	NE	Southern Western Ghats	Rao *et al*., 2019
73	*Lophopetalum wightianum* Arn.	Celestraceae	LC	Not Endemic	Rao *et al*., 2019
74	*Macaranga peltata* (Roxb.) Muell.-Arg.	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
75	*Maesa indica* (Roxb.) A.DC.	Myrsinaceae	NE	Not Endemic	Rao *et al.,* 2019
76	*Mallotus philippensis* (Lamk.)Muell.-Arg.	Euphorbiaceae	LC	Not Endemic	Rao *et al*., 2019
77	*Mangifera indica* L.	Anacardiaceae	DD	Not Endemic	Rao *et al*., 2019
78	*Mastixia arborea arborea* (Wight) Bedd.	Cornaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
79	*Meiogyne pannosa* (Dalzell) J. Sinclair	Annonaceae	NE	Not Endemic	Rao *et al.,* 2019
80	*Melia dubia* Cav.	Meliaceae	NE	Not Endemic	Rao *et al*., 2019
81	*Memocylon umbellatum* N.Burman	Melastomataceae	NE	Not Endemic	Rao *et al*., 2019
82	*Mesua ferrea* L.	Clusiaceae	NE	Not Endemic	Rao *et al*., 2019
83	*Michelia nilagirica* Zenker	Magnoliaceae	VU	Not Endemic	Rao *et al*., 2019
84	*Miliusa wightiana* Hook. f. & Thomson	Annonaceae	NE	Western Ghats	Ramesh and Pascal., 1997
85	*Murayya paniculata* (L.)W.Jack	Rutaceae	NE	Not Endemic	Rao *et al*., 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
86	*Myristica dactyloides* Gaertn	Myristicaceae	EN	Not Endemic	Rao *et al*., 2019
87	*Myristica fatua* var. magnifica (Bedd.) Sinclair	Myristicaceae	EN	Western Ghats	Ramesh and Pascal., 1997
88	*Myristica fragrans* Houtt.	Myristicaceae	DD	Not Endemic	Rao *et al*., 2019
89	*Myristica malabarica* Lam.	Myristicaceae	LC	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
90	*Neolitsea scrobiculata* (Meisn.) Gamble	Lauraceae	NE	Not Endemic	Rao *et al.,* 2019
91	*Nothopegia colebrookiana* (Wight) Bl.	Anacardiaceae	NE	Not Endemic	Rao *et al*., 2019
92	*Nothopodytes nimmoniana* (Graham) Mabb.	Icacinaceae	NE	Not Endemic	Rao *et al*., 2019
93	*Otonephelium stipulaceum* (Bedd.) Radlk.	Sapindaceae	NE	Western Ghats	Rao et al., 2019
94	*Palaquium ellipticum* (Dalzell) Baill.	Sapotaceae	NE	Western Ghats	Rao *et al*., 2019
95	*Paracroton pendalus* ssp.zeylanicus	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
96	*Persea macrantha* (Nees) Kosterm.	Lauraceae	NE	Not Endemic	Rao *et al.,* 2019
97	*Poeciloneuron indicum* Bedd.	Clusiaceae	NE	Western Ghats	Ramesh and Pascal, 1997
98	*Polyalthia fragrans* (Dalzell) Hook. f. & Thomson	Annonaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
99	*Pongamia pinnata* (L.) Pierre	Fabaceae	LC	Not Endemic	Rao *et al*., 2019
100	*Psydrax dicoccos* Gaertn. Var. dicoccos	Rubiaceae	NF	Not Endemic	Rao *et al*., 2019
101	*Pterospermum diversifolium* Bl.	Sterculiaceae	NF	Not Endemic	Rao *et al*., 2019
102	*Sapindus laurifolius* L.	Sapindaceae	NF	Not Endemic	Rao *et al*., 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
103	*Schleichera oleosa* (L.) Oken	Sapindaceae	NE	Not Endemic	Rao *et al*., 2019
104	*Stereospermum colais* (Buch.-Ham. Ex Dillw.D.Mabberley	Bignoniaceae	NE	Not Endemic	Rao *et al*., 2019
105	*Strombosia ceylanica Gardn.*	Opiliaceae	NE	Not Endemic	Rao *et al*., 2019
106	*Symplocos cochinchinensis* (Lour.)	Symplocaceae	NE	Not Endemic	Rao *et al*., 2019
107	*Syzygium cumuni* (L.) Skeels	Myrtaceae	NE	Not Endemic	Rao *et al.,* 2019
108	*Syzygium densiflorum* Wall. ex Wight &Arn.	Myrtaceae	VU	Western Ghats	Ramesh and Pascal, 1997
109	*Syzygium gardnerii* Thw.	Myrtaceae	NE	Not Endemic	Rao *et al*., 2019
110	*Syzygium hemisphericum* (Wt.) Alston	Myrtaceae	NE	Not Endemic	Rao *et al.,* 2019
111	*Syzygium mundagam* (Bourd.) Chitra	Myrtaceae	VU	Not Endemic	Ramesh and Pascal, 1997; Rao *et al*., 2019
112	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	NE	Not Endemic	Rao *et al*., 2019
113	*Terminalia paniculata* Roth.	Combretaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
114	*Turpinia malabarica* Gamble	Staphyleaceae	NE	Not Endemic	Ramesh and Pascal, 1997
115	*Vateria indica* L.	Dipterocarpaceae	CE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
116	*Vernonia travancorica* Hook. f.	Asteraceae	NE	Western Ghats	Ramesh and Pascal,1997
117	*Vitex altissma* L.f.	Verbenaceae	NE	Not Endemic	Rao *et al*., 2019
118	*Xanthophyllum arnottianum* Wight.	Xanthophyllaceae	VU	Western Ghats	Rao *et al*., 2019
119	*Xylopia parviflora* (Wight) Hook. F.& Thomson	Annonaceae	NF	Not Endemic	Rao et al., 2019

(NF- Not Found; NE- Not Evaluated; VU- Vulnerable; EN- Endangered; LC- Least Concern CE; Critically endangered)

Appendix XVIII. Details of tree species recorded in West Coast Tropical Semi-evergreen Forest (WCTSE)

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
1	*Actinodaphne malabarica* Balakr	Lauraceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
2	*Aglaia lawii*	Meliaceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao et al., 2019
3	*Agrostistachys borneensis* Becc.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
4	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	LC	Not Endemic	Rao *et al*., 2019
5	*Anacolosa densiflora* Bedd.	Aptandraceae	EN	Southern Western Ghats	Rao *et al*., 2019
6	*Anthocephalus cadamba*	Rubiaceae	NE	Not Endemic	Rao *et al.,* 2019
7	*Antiaris toxicaria* (Pers.) Lesch.	Moraceae	LC	Not Endemic	Rao *et al*., 2019
8	*Antidesma menasu* (Tul.)Miq. Ex Muell.-Arg.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
9	*Aporosa bourdillonii* Stapf	Euphorbiaceae	DD	Southern Western Ghats	Ramesh and Pascal, 1997; Rao et al., 2019
10	*Aporosa cardiosperma* (Gaertn.) Merr.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
11	*Artocarpus gomezianus zeylanicus* Jarrett	Moraceae	NE	Not Endemic	Rao *et al.,* 2019
12	*Artocarpus hirsutus* Lam.	Moraceae	LC	Western Ghats	Ramesh and Pascal., 2019
13	*Atalantia racemosa* Wight & Arn.	Rutaceae	NE	Not Endemic	Rao *et al*., 2019
14	*Baccaurea courtallensis* (Wight) Muell.-Arg.	Euphorbiaceae	NT	Not Endemic	Rao *et al*., 2019
15	*Bischofia javanica* Blume	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
16	*Bombax ceiba* L.	Malvaceae	NE	Not Endemic	Rao *et al*., 2019
17	*Buchanania lanceolata* Wight	Anacardiaceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
18	*Calophyllum polyanthum* Wall.ex Choisy	Clusiaceae	NE	Southern Western Ghats	Rao *et al*., 2019
19	*Canarium strictum* Roxb.	Burseraceae	NE	Not Endemic	Rao *et al*., 2019
20	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	NE	Not Endemic	Rao *et al.,* 2019
21	*Cassia fistula* L.	Fabaceae	LC	Not Endemic	Rao *et al*., 2019
22	*Celtis philippensis* Blanco	Cannabaceae	LC	Not Endemic	Rao *et al*., 2019
23	*Chionanthus mala-elengi* (Dennst.) P.S. Green	Oleoceae	NE	Not Endemic	Rao *et al*., 2019
24	*Cinnamomum malabatrum* (Burm.f.) Presl	Lauraceae	NF	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
25	*Croton malabaricus* Bedd.	Euphorbiaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997
26	*Dillenia pentagyna* Roxb.	Dilleniaceae	NE	Not Endemic	Rao *et al*., 2019
27	*Dimocarpus longan* Lour.	Sapindaceae	NT	Not Endemic	Rao *et al.,* 2019
28	*Diospyros buxiflora* (Blume) Hiern	Ebenaceae	NE	Not Endemic	Rao *et al*., 2019
29	*Diospyros candolleana* Wight.	Ebenaceae	VU	Western Ghats	Ramesh and Pascal, 1997
30	*Diospyros foliosa* Wall.	Ebenaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
31	*Diospyros montana* Roxb.	Ebenaceae	NE	Not Endemic	Rao *et al.,* 2019
32	*Diospyros paniculata* Dalz.	Ebenaceae	VU	Western Ghats	Ramesh and Pascal, 1997
33	*Dipterocarpus bourdillonii* Brandis	Dipterocarpaceae	EN	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
34	*Dipterocarpus indicus* Bedd.	Dipterocarpaceae	EN	Western Ghats	Ramesh and Pascal, 1997
35	*Dysoxylum malabaricum* Bedd.ex Hiern.	Meliaceae	EN	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
36	*Elaeocarpus serratus* L.	Elaeocarpaceae	NE	Not Endemic	Rao *et al*., 2019
37	*Ficus drupacea pubescens*	Moraceae	NE	Not Endemic	Rao *et al*., 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
38	*Flacourtia montana* J. Graham.	Salicaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
39	*Garcinia gummi-gutta*	Clusiaceae	LC	Not Endemic	Rao *et al.,* 2019
40	*Glochidion ellipticum* Wight	Euphorbiaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
41	*Glochidion zeylanicum* (Gaertn.) A.Jussieu	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
42	*Gmelina arborea* Roxb.ex Sm.	Lamiaceae	NE	Not Endemic	Rao *et al.,* 2019
43	*Grewia tiliifolia* Vahl	Malvaceae	NE	Not Endemic	Rao *et al*., 2019
44	*Haldina cordifolia* (Roxb.)Ridsd.	Rubiaceae	NE	Not Endemic	Rao *et al.,* 2019
45	*Holigarna arnottiana* Hook.f.	Anacardiaceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997
46	*Hopea panga* (Dennst.) Mabb.	Dipterocarpaceae	EN	Western Ghats	Rao *et al*., 2019
47	*Hopea parviflora* Bedd.	Dipterocarpaceae	EN	Western Ghats	Ramesh and Pascal, 1997
48	*Hydnocarpus alpina* Wight	Achariaceae	NE	Not Endemic	Rao *et al*., 2019
49	*Hydnocarpus pentandra* (Buch.-Ham) Oken	Achariaceae	VU	Western Ghats	Rao *et al.,* 2019
50	*Ixora brachiata* Roxb.	Rubiaceae	NE	Not Endemic	Rao *et al*., 2019
51	*Kingiodendron pinnatum* (Roxb.ex DC.)	Fabaceae	EN	Western Ghats	Ramesh and Pascal, 1997
52	*Knema attenuata* Warb	Myristicaceae	LC	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
53	*Lagerstroemia microcarpa* Wight	Lythraceae	NF	Western Ghats	Rao *et al.,* 2019
54	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	NE	Not Endemic	Rao *et al*., 2019
55	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	NE	Not Endemic	Rao *et al.,* 2019
56	*Litsea corieacea*Hook.f.	Lauraceae	NE	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
57	*Lophopetalum wightianum* Arn.	Celestraceae	LC	Not Endemic	Rao *et al.,* 2019
58	*Macaranga indica*	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
59	*Macaranga peltata* (Roxb.) Mull. Arg.	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
60	*Mallotus philippensis* (Lam.) Mull.-Arg.	Euphorbiaceae	LC	Not Endemic	Rao *et al.,* 2019
61	*Mangifera indica* L.	Anacardiaceae	DD	Not Endemic	Rao *et al.,* 2019
62	*Mastixia arborea arborea*	Cornacea	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
63	*Melia dubia*	Meliaceae	NE	Not Endemic	Rao *et al.,* 2019
64	*Melicope-lunu-ankeda* (Gaertn.) Hartley	Rutaceae	EN	Not Endemic	Rao *et al.,* 2019
65	*Memecylon umbellatum* N. Burman	Melastomataceae	NE	Not Endemic	Rao *et al.,* 2019
66	*Mesua ferrea* L.	Clusiaceae	NE	Not Endemic	Rao *et al.,* 2019
67	*Miliusa wightiana* Hook. F. & Thoms.	Annonaceae	NE	Western Ghats	Rao *et al.,* 2019
68	*Mitragyna parviflora (Roxb.) Korth*	Rubiaceae	NE	Not Endemic	Rao *et al.,* 2019
69	*Myristica dactylaides*	Myristicaceae	VU	Not Endemic	Rao *et al.,* 2019
70	*Myristica malabarica Lam*	Myristicaceae	LC	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
71	*Olea dioica* Roxb.	Oleaceae	NE	Not Endemic	Rao *et al*., 2019
72	*Ostodes zeylanica* (Thw.) Muell	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
73	*Otonephelium stipulaceum* (Bedd.) Radlk.	Sapindaceae	NT	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
74	*Pajanelia longifolia* (Willd) K. Schum.	Bignoniaceae	NE	Not Endemic	Rao *et al.,* 2019
75	*Palaquium ellipticum* (Dalz.) Engl.	Sapotaceae	NE	Western Ghats	Rao *et al.,* 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
76	*Persea macrantha* (Nees) Kosterm.	Lauraceae	NE	Not Endemic	Rao *et al.,* 2019
77	*Poeciloneuron indicum* Bedd.	Clusiaceae	NE	Western Ghats	Ramesh and Pascal, 1997
78	*Polyalthia fragrans* (Dalz.) Bedd.	Annonaceae	NE	Western Ghats	Ramesh and Pascal,1997; Rao *et al.,* 2019
79	*Pongamia pinnata* (L.) Pierre	Fabaceae	LC	Not Endemic	Rao *et al.,* 2019
80	*Psydax dioccos* Gaertn. Var. dicoccos	Rubiaceae	NF	Not Endemic	Rao *et al.,* 2019
81	*Pterospermum diversifolium* Bl	Malvaceae	NE	Not Endemic	Rao *et al*., 2019
82	*Pterygota alata* (Roxb.) R.Br.	Malvaceae	NE	Not Endemic	Rao *et al*., 2019
83	*Sapindus laurifolius* Vahl.	Sapindaceae	NE	Not Endemic	Rao *et al.,* 2019
84	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	LC	Not Endemic	Rao *et al*., 2019
85	*Solenocarpus indicus* Wight & Arn.	Anacardiaceae	NE	Not Endemic	Rao *et al.,* 2019
86	*Sterculia guttata* Roxb.	Malvaceae	NE	Not Endemic	Rao *et al.,* 2019
87	*Stereospermum colais* (Buch.-Ham.ex Dillw.) Mabb.	Bignoniaceae	NE	Not Endemic	Rao *et al*., 2019
88	*Strombosia ceylanica* Gardn.	Strombosiaceae	NE	Not Endemic	Rao *et al*., 2019
89	*Strychnos-nux-vomica* L.	Loganiaceae	NE	Not Endemic	Rao *et al.,* 2019
90	*Syzygium cumini* (L.) Skeels	Myrtaceae	LC	Not Endemic	Rao *et al.,* 2019
91	*Syzygium gardneri* Thw.	Myrtaceae	NE	Not Endemic	Rao *et al.,* 2019
92	*Syzygium hemispericum* (Wight) Alston	Myrtaceae	NE	Not Endemic	Rao *et al.,* 2019
93	*Syzygium mundagam* (Bourd.) Chitra	Myrtaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
94	*Tabernaemontana alternifolia* L.	Apocynaceae	NE	Southern Western Ghats	Rao *et al.,* 2019
95	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	NE	Not Endemic	Rao *et al.,* 2019

S/No.	Name of Species	Family	Conservation Status	Endemism	Reference
96	*Terminalia paniculata* Roth.	Combretaceae	NE	Southern Western Ghats	Rao *et al.,* 2019
97	*Tetrameles nudiflora* R. Br.	Datiscaceae	LC	Not Endemic	Rao *et al.,* 2019
98	*Vateria indica* L.	Dipterocarpaceae	CE	Western Ghats	Ramesh and Pascal, 1997;Rao *et al*., 2019
99	*Vitex altissma* L.	Lamiaceae	NE	Not Endemic	Rao *et al*., 2019
100	*Xanthophyllum arnottianum* Wight	Xanthophyllaceae	VU	Western Ghats	Rao *et al.,* 2019
101	*Xylopia parviflora*	Annonaceae	NE	Not Endemic	Rao *et al.,* 2019

(NF- Not Found; NE- Not Evaluated; VU- Vulnerable; EN- Endangered; LC- Least Concern CE; Critically endangered)

Appendix XIX. Details of tree species recorded in Southern Secondary Moist Deciduous Forest (SSMDF)

S/No.	**Name of species**	**Family**	**Conservation Status**	**Endemism**	**Reference**
1	*Ailanthus triphysa* (Dennst.) Alston.	Simaroubaceae	NE	Not Endemic	Rao *et al.,* 2019
2	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	LC	Not Endemic	Rao *et al.,* 2019
3	*Aporosa cardiosperma* (Gaertn.) Merr.	Euphorbiaceae	VU	Not Endemic	Rao *et al*., 2019
4	*Bombax ceiba* L.	Malvaceae	LC	Not Endemic	Rao *et al*., 2019
5	*Bombax insigne* Wall	Malvaceae	NE	Not Endemic	Rao *et al*., 2019
6	*Bridelia retusa* (L.) Spreng.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
7	*Buchanania lanzan* Spreng.	Anacardiaceae	NE	Not Endemic	Rao *et al*., 2019
8	*Careya arborea* Roxb.	Lecythidaceae	NE	Not Endemic	Rao *et al*., 2019
9	*Cassia fistula* L.	Fabaceae	LC	Not Endemic	Rao *et al.,* 2019
10	*Cinnamomum malabatrum* (Burm.f.) Presl.	Lauraceae	NE	Southern Western Ghats	Rao *et al*., 2019; Ramesh and Pascal,1997
11	*Chionanthus mala-elengi*	Olaceae	NE	Southern Western Ghats	Rao *et al*., 2019
12	*Dalbergia latifolia* Roxb.	Fabaceae	VU	Not Endemic	Rao *et al*., 2019
13	*Dalbergia sissoides Grah.* ex Wight & Arn.	Fabaceae	NE	Not Endemic	Rao *et al.,* 2019
14	*Dillenia pentagyna* Roxb.	Dilleniacaceae	NE	Not Endemic	Rao *et al*., 2019
15	*Diospyros buxifolia* (Blume) Hiern	Ebenaceae	NE	Not Endemic	Rao *et al*., 2019
16	*Elaeocarpus serratus*	Elaeocarpaceae	NE	Not Endemic	Rao *et al*., 2019
17	*Elaeocarpus tectorius* (Lour.) Poir.	Elaeocarpaceae	NE	Not Endemic	Rao *et al*., 2019
18	*Grewia tiliifolia* Vahl.	Malvaceae	NE	Not Endemic	Rao *et al.,* 2019
19	*Haldina cordifolia* (Roxb.) Ridsdale	Rubiaceae	NE	Not Endemic	Rao *et al*., 2019

S/No.	Name of species	Family	Conservation Status	Endemism	Reference
20	*Holarrhena pubescens* (Buch.-Ham.) Wall. ex Don	Apocynaceae	LC	Not Endemic	Rao *et al*., 2019
21	*Hydnocarpus pentandrus* Buch.- Ham Oken	Flacourtiaceae	VU	Western Ghats	Rao *et al*., 2019; Ramesh and Pascal,1997
22	*Hymenodictyon obovatum* Wall.	Rubiaceae	NE	South India	Rao *et al.,* 2019
23	*Hymenodictyon orixense* (Roxb.) Mabb.	Rubiaceae	NE	Not Endemic	Rao *et al*., 2019
24	*Ixora brachiata Roxb.* ex DC.	Rubiaceae	NE	Not Endemic	Rao *et al.,* 2019
25	*Lagerstroemia microcarpa* Wight	Rubiaceae	NE	Western Ghats	Rao *et al.,* 2019
26	*Lagerstroemia flos-reginae* Roxb.	Lythraceae	NE	Not Endemic	Rao *et al*., 2019
27	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	NE	Not Endemic	Rao *et al.,* 2019
28	*Litsea coriacea* (Heyne ex Wall.) Hook.f.	Lauraceae	NE	Southern Western Ghats	Rao *et al*., 2019
29	*Macaranga peltata* (Roxb.) Muell.-Arg.	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
30	*Macaranga indica* Wight	Euphorbiaceae	LC	Not Endemic	Rao *et al*., 2019
31	*Mallotus philippensis* (Lamk.) Muell.-Arg.	Euphorbiaceae	LC	Not Endemic	Rao *et al*., 2019
32	*Mallotus tetracoccus* (Roxb.) Kurz	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
33	*Melicope-lunu-ankenda* (Gaertn.) Hartley	Rutaceae	EN	Not Endemic	Rao *et al*., 2019
34	*Miliusa tomentosa* (Roxb.) J. Sinclair	Annonaceae	NE	Not Endemic	Rao *et al*., 2019
35	*Mitragyna Parvifolia* (Roxb.) Kunth	Rubiaceae	NE	Not Endemic	Rao *et al*., 2019
36	*Naringi crenulata* (Roxb.) D.H Nicolson	Rutaceae	NE	Not Endemic	Rao *et al*., 2019
37	*Olea dioica* Roxb.	Oleaceae	NE	Not Endemic	Rao *et al*., 2019
38	*Phyllanthus emblica* L.	Euphorbiaceae	NE	Not Endemic	Rao *et al.,* 2019
39	*Pongamia pinnata* (L.) Pierre	Fabaceae	LC	Not Endemic	Rao *et al*., 2019

S/No.	Name of species	Family	Conservation Status	Endemism	Reference
40	*Pterocarpus marsupium* Roxb.	Fabaceae	NT	Not Endemic	Rao *et al*., 2019
41	*Pterygota alata* (Roxb.) R. Br.	Malvaceae	NE	Not Endemic	Rao *et al*., 2019
42	*Schleichera oleosa* L.	Sapindaceae	NE	Not Endemic	Rao *et al.,* 2019
43	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	NE	Not Endemic	Rao *et al*., 2019
44	*Sterculia balanghas* Ait.	Sterculiaceae	NE	Not Endemic	Rao *et al*., 2019
45	*Sterculia guttata* Roxb.	Malvaceae	NE	Not Endemic	Rao *et al.,* 2019
46	*Stereospermum colais* (Buch.-Ham.ex Dillw.) D.L. Mabberley	Bignoniaceae	NE	Not Endemic	Rao *et al*., 2019
47	*Strychnos-nux-vomica* L.	Loganiaceae	NE	Not Endemic	Rao *et al*., 2019
48	*Tabernaemontana alternifolia* L.	Apocynaceae	NT	Southern Western Ghats	Rao *et al.,* 2019
49	*Tamarindus indica* L.	Fabaceae	NE	Not Endemic	Rao *et al*., 2019
50	*Terminalia paniculata* Roth.	Combretaceae	NE	Peninsular India	Rao *et al*., 2019
51	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	NE	Not Endemic	Rao *et al.,* 2019
52	*Terminalia crenulata* Heyne ex Roth.	Combretaceae	NE	Not Endemic	Rao *et al*., 2019
53	*Terminalia elliptica* Willd.	Combretaceae	NE	Not Endemic	Rao *et al*., 2019
54	*Tetrameles nudiflora* R.Br.	Tetramelaceae	LC	Not Endemic	Rao *et al*., 2019
55	*Vitex altissima* L.	Lamiaceae	NE	Not Endemic	Rao *et al*., 2019
56	*Wrightia arborea* (Dennst.) D.J. Mabb.	Apocynaceae	NE	Not Endemic	Rao *et al.,* 2019
57	*Wrightia tinctoria* (Roxb.)R. Br.	Apocynaceae	NE	Not Endemic	Rao *et al.,* 2019
58	*Xanthophyllum arnottianum* Wight	Xanthophyllaceae	VU	Western Ghats	Rao *et al*., 2019

(NF- Not Found; NE- Not Evaluated; VU- Vulnerable; EN- Endangered; LC- Least Concern CE; Critically endangered)

Appendix XX. Details of tree species recorded in Myristica Swamp Forest (MSF)

S/No	Name of the Species	Family	Conservation Status	Endemism	Reference
1	*Aporosa bourdillonii* Stapf	Euphorbiaceae	EN	Southern Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
2	*Aporosa cardiosperma* (Gaertn.) Merr.	Euphorbiaceae	VU	Not Endemic	Rao *et al*., 2019
3	*Atalantia racemosa* Wight &Arn.	Rutaceae	NE	Not Endemic	Rao *et al.,* 2019
4	*Baccaurea courtallensis* (Wight) Mull.Arg.	Euphorbiaceae	NE	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
5	*Buchanania axillaris* (Desr.) T.P. Ramamoorthy	Anacardiaceae	NE	Not Endemic	Rao *et al.,* 2019
6	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Lauraceae	NE	Southern Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997
7	*Diospyros foliolosa* (Rich.ex A.Gray) Bakh.	Ebenaceae	NE	Southern Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
8	*Diospyros paniculata* Dalzell.	Ebenaceae	VU	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
9	*Dysoxylum macrocarpum* Bedd	Meliaceae	NE	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
10	*Garcinia gummi-gutta* (L.) Robs.	Clusiaceae	NE	Western Ghats	Ramesh and Pascal 1997; Rao *et al*., 2019
11	*Gomphandra coriacea* Wight	Stemnuraceae	NE	Not Endemic	Rao *et al.,* 2019
12	*Gymnacranthera farquhariana* Warb.	Myristicaceae	NE	Not Endemic	Rao *et al*., 2019
13	*Haldina cordifolia* Roxb.	Rubiaceae	NE	Not Endemic	Rao *et al*., 2019
14	*Holigarna arnottiana* Wall.ex Hook.f	Anacardiaceae	NE	Southern Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997

S/No	Name of the Species	Family	Conservation Status	Endemism	Reference
15	*Hopea malabarica*	Dipterocarpaceae	EN	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
16	*Hopea parviflora* Bedd.	Dipterocarpaceae	EN	Southern Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997
17	*Humboltia vahliana* Wight	Fabaceae	LC	Not Endemic	Rao *et al*., 2019
18	*Hydnocarpus pentandra* (Buch.-Ham.) Oken	Flacourtiaceae	VU	Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997
19	*Kingiodendron pinnatum* (DC.) Harms	Fabaceae	EN	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
20	*Knema attenuata* Warb.	Myristicaceae	LC	Western Ghats	Rao *et al.,* 2019
21	*Lagerstroemia flos-reginae* Roxb.	Lythraceae	NE	Not Endemic	Rao *et al*., 2019
22	*Lannea coromandelica* (Hout.) Merr.	Anacardiaceae	NE	Not Endemic	Rao *et al.,* 2019
23	*Lophopetalum wightianum* Arn.	Celastraceae	LC	Not Endemic	Rao *et al*., 2019
24	*Mastixia arborea arborea* (Wight) Bedd.	Cornaceae	NE	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
25	*Melicope lunu-ankenda* (Gaertn.) T.G. Hartley	Rutaceae	EN	Not Endemic	Rao *et al.,* 2019
26	*Mesua ferrea* L.	Calophyllaceae	NE	Not Endemic	Rao *et al.,* 2019
27	*Mitragyna parvifolia* Roxb.	Rubiaceae	NE	Not Endemic	Rao *et al.,* 2019
28	*Mitrephora grandiflora* Bedd.	Annonaceae	VU	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
29	*Myristica dactyloides* Gaertn.	Myristicaceae	VU	Western Ghats	Rao *et al.,* 2019; Ramesh and Pascal 1997
30	*Myristica fatua* Houtt.var. magnifica (Bedd.) Sinclair	Myristicaceae	EN	Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997

S/No	Name of the Species	Family	Conservation Status	Endemism	Reference
31	*Myristica malabarica* Lam.	Myristicaceae	VU	Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997
32	*Vateria indica* L.	Dipterocarpaceae	CE	Western Ghats	Rao *et al*., 2019; Ramesh and Pascal 1997
33	*Xanthophyllum arnottianum* Wight	Polygalaceae	NE	Western Ghats	Rao *et al.,* 2019

(NF- Not Found; NE- Not Evaluated; VU- Vulnerable; EN- Endangered; LC- Least Concern CE; Critically endangered)

Appendix XXI. Details of the tree species recorded in the Tropical Hilltop Forest (THF)

S/No.	Name of the species	Family	Conservation Status	Endemism	Reference
1	*Actinodaphne campanulata* Hook.f.	Lauraceae	VU	Southern Western Ghats	Rao *et al.,* 2019
2	*Actinodaphne malabarica* Balakr.	Lauraceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
3	*Aglaia bourdillonii* Gamble	Meliaceae	VU	Southern Western Ghats	Rao *et al.,* 2019
4	*Agrostistachys borneensis* Beec.	Euphorbiaceae	NE	Not Endemic	Rao *et al*., 2019
5	*Ardisia blatteri* Gamble	Myrsinaceae	EN	Southern Western Ghats	Rao *et al.,* 2019
6	*Ardisia rhomboidea* Wight	Myrsinaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
7	*Bhesa indica* (Bedd.) Ding Hou	Calestraceae	NE	Not Endemic	Rao *et al.,* 2019
8	*Calophyllum polyanthum* Wall. ex Choisy	Clusiaceae	NE	Not Endemic	Rao *et al*., 2019
9	*Celtis timerensis* Span.	Ulmaceae	NE	Not Endemic	Rao *et al*., 2019
10	*Chionanthus mala-elengi*	Oleaceae	NE	Southern Western Ghats	Rao *et al*., 2019
11	*Cinnamomum sulphuratum* Nees	Lauraceae	VU	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
12	*Cinnamomum verum* V.S. Presl.	Lauraceae	NE	Not Endemic	Rao *et al*., 2019
13	*Cinnomomum perrorretti* Meisn	Lauraceae	VU	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
14	*Dimocarpus longan*	Sapindaceae	NE	Not Endemic	Rao *et al*., 2019
15	*Elaeocarpus munronii* (Wight) Mast.	Elaeocarpaceae	LC	Southern Western Ghats	Ramesh and Pascal, 1997

S/No.	Name of the species	Family	Conservation Status	Endemism	Reference
16	*Eugenia discifera* Gamble	Myrtaceae	EN	Southern Western Ghats	Rao *et al*., 2019
17	*Fagraea ceilanica* Thunb.	Lauraceae	NE	Not Endemic	Rao *et al.,* 2019
18	*Ficus tsjahela* Burm.	Moraceae	NE	Not Endemic	Rao *et al*., 2019
19	*Garcinia cowa* Roxb.ex DC.	Clusiaceae	NE	Not Endemic	Rao *et al*., 2019
20	*Garcinia imberti Bourd.*	Clusiaceae	EN	Southern Western Ghats	Rao *et al.,* 2019
21	*Garcinia travancorica* Bedd.	Clusiaceae	VU	Southern Western Ghats	Rao *et al*., 2019
22	*Gluta travancorica*	Anacardiaceae	EN	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
23	*Gomphondra coriacea* Wight	Stemonuraceae	NE	Not Endemic	Rao *et al.,* 2019
24	*Goniothalamus rhynchantherus Dunn.*	Annonaceae	EN	Western Ghats	Rao *et al.,* 2019
25	*Goniothalamus wightii*	Annonaceae	EN	Southern Western Ghats	Rao et al., 2019
26	*Gordonia obtusa* Wall.ex Wight & Arn	Theaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao et al., 2019
27	*Hydnocarpus alpina* Wight	Achariaceae	VU	Not Endemic	Rao *et al.,* 2019
28	*Litsea floribunda*	Lauraceae	NE	Western Ghats	Rao *et al.,* 2019
29	*Litsea keralana* Kosterm. Insignis	Lauraceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
30	*Litsea oleoides* Hook. f.	Lauraceae	NE	Southern Western Ghats	Rao *et al.,* 2019
31	*Maesa indica* (Roxb.) A.DC.	Myrsinaceae	NE	Not Endemic	Rao *et al.,* 2019

S/No.	Name of the species	Family	Conservation Status	Endemism	Reference
32	*Mastixia arborea* (Wight) Bedd.	Cornaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019
33	*Melisoma pinnata subsp. arnottiana*	Sabiaceae	NE	Not Endemic	Rao *et al.,* 2019
34	*Miliusa wightiana* Hook. f. &Thomson	Annonaceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al*., 2019
35	*Naringi crenulata (*Roxb.) Nicolson	Rutaceae	NE	Not Endemic	Rao *et al.,* 2019
36	*Neolitsea scrobiculata* (Meissn.) Gamble	Lauraceae	NE	Southern Western Ghats	Rao *et al.,* 2019
37	*Octotropis travancorica* Bedd.	Rubiaceae	VU	Southern Western Ghats	Rao *et al*., 2019
38	*Poecilonueron indicus* Bedd.	Clusiaceae	NE	Western Ghats	Ramesh and Pascal, 1997
39	*Symplocos cochinchinensis* (Lour.) S.Moore SSP.Laurina (Retz.) Noot	Symplocaceae	NE	Western Ghats	Rao *et al.,* 2019
40	*Syzygium caryophyllatum* (L.)Alston	Myrtaceae	EN	Not Endemic	Rao *et al*., 2019
41	*Syzygium densiflorum* Wall. ex Wight & Arn.	Myrtaceae	VU	Southern Western Ghats	Ramesh and Pascal, 1997; Rao *et* al*.,* 2019
42	*Syzygium rubicundum* Wight & Arn.	Myrtaceae	VU	Southern Western Ghats	Rao *et al.,* 2019
43	*Turpinia malabarica* Gamble	Staphyleaceae	NE	Not Endemic	Rao *et al*., 2019
44	*Vernonia travancorica* Hook. f.	Asteraceae	NE	Western Ghats	Ramesh and Pascal, 1997; Rao *et al.,* 2019

(NF- Not Found; NE- Not Evaluated; VU- Vulnerable; EN- Endangered; LC- Least Concern CE; Critically endangered)