FLORISTIC AND EDAPHIC ATTRIBUTES OF A SHOLA FOREST ECOSYSTEM IN MANKULAM FOREST DIVISION, KERALA

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "Floristic and edaphic attributes of a shola forest ecosystem in Mankulam Forest Division, Kerala" is a bonafide record of research done by me during the course of research and that this thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar titles, of any other University or Society.

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Introduction

1. INTRODUCTION

Tropical Montane Cloud Forest (TMCF), which is confined to only 0.14% of the soil surface of the earth, is an ecologically specific and hydrologically important ecosystem (Scatena *et al*., 2010). TMCF's primary occurring area today in the world is Asia, especially Indonesia and Papua New Guinea, followed by the Americas. They occur mostly at altitudes between 1200 m and 2800 m with records of upto 4000 meters and some upto 3500 meters. Western Ghats cloud forests, also known as sholas, are located in a hotspot with world-renowned biodiversity and can provide useful insight into international efforts to retain TMCF (Myers, 2003). Montane grasslands are increasingly being depleted in various parts of the world and substantial alterations are reported for shola sky-islands of Western Ghats also (Arasumani *et al*., 2018).

TMCF are marked by stunted evergreen trees with thick, oval, or umbrella-shaped crown made up of entire and coriaceous leaves (Chandrasekhara *et al*., 2006). A lower number of wooden climbers are present, whereas non-vascular epiphytes, including mosses and liverworts, are much higher. The TMCF’s stand properties are related to the elevation gradient, temperature and humidity. Therefore, based on these features, TMCF is further split into lower and upper mountains (Ashton, 2003; Scatena *et al*., 2010).

Sholas are located mainly in Western Ghats at the high elevations of the Nilgiri and Palani hills (Mohandass *et al*., 2008). This ecosystem is found to be shaped and sustained by a combination of factors like aspect, temperature, and rainfall, (Caner *et al*., 2007) or by a combination of slope, wetness, and shape of the landscape (Bunyan *et al*., 2012). The montane shola- grassland ecosystems of Western Ghats are known to host unique assemblages of endemic and threatened species of plants (Somasundaram and Vijayan, 2010), birds (Nameer *et al*., 2001), mammals and amphibians (Inger *et al*., 1987). A higher proportion of tree flora is known to be endemic to these habitats (Nair and Menon, 2001) and the dominating tree families in this ecosystem is identified as Lauraceae and Symplocaceae (Robin and Nandini, 2012).

The micro-climate within the shola patches was preserved between 31 °C and 16 °C with micro-environment and soil conditions exhibiting significant variations at edge-inner gradients (Thomas and Shankar, 2001). The tree species in shola forests are able to absorb water and nutrients directly from their leaves and are found very resistant to drought (Goldsmith *et al*., 2013, Oliveira *et al*., 2014). Shola forests rely on various altitudes and local micro-environment (Mohandass *et al.*, 2016), variety of organisms, human population and composition of the forests. Throughout Western Ghats, there is evidence of climate control over the distribution of forest and grasslands through mosaics.

Western Ghats mosaics are just below tropical forest line (Korner, 1998). Temperature is the main limiting factor for tree line growth. Less average soil and air temperatures above 2000 m can restrict the establishment and longevity of most tropical trees (Korner and Paulsen, 2004). Differences in the relationships between environment and topography (Jarvis and Mulligan, 2011) give rise to large variations in the altitude and latitude of cloud forests which can explain why shola forests are near to topographically varying areas with high precipitation. The appearance and distribution of tropical introduced plants, recognized as a major threat to grasslands, may well be aggravated by the interaction between ground cover and climate change (Srivastava, 2001; Zarri *et al*., 2006; Thomas and Palmer, 2007).

In Kerala, the shola forests are found extensively along the high ranges. They are found all along the upper reaches of the Western Ghats, where the elevation goes beyond 1,500 m above main sea level (Swarupanandan *et al*., 1998). The Mankulam forest division coming under the high range circle of Kerala consists of shola forests designated as southern montane wet temperate forests (11A/C1) (GOK, 2012). It is seen in depression of valleys and between hillocks of Pampadumpara adjacent area of

Eravikulam national park, and in the southern side of Kadalar in Ottakkallu areas of the division.

Shola habitats are areas of high biodiversity but also face multiple potential risks. Due to the disproportionate amounts of endemic biodiversity, they host, the ecological resources they offer and the reality that they are among the most vulnerable ecosystems globally, immediate conservation action is required. It is important to examine whether the shola forest exhibits high floristic diversity, structure and soil properties comparable to tropical evergreen forests for prioritizing the conservation activities in the protected areas. It is in this background this study was undertaken with the following objectives.

1. To characterize the floristic composition, diversity and vegetation structure of a shola forest ecosystem located in Mankulam Forest Division.

2. To investigate the physico-chemical properties of soil that supports this unique forest ecosystem.

Review of Literature

2. REVIEW OF LITERATURE

2.1 SHOLA FOREST

Tropical Montane Cloud Forest (TMCF) are characterized as forests that are constantly (Hamilton *et al*. 1995) submerged on mist. These hydrologically important and ecologically unique habitats are limited to only 0.14 percent of the earth's surface area (Bruijnzeel and Proctor, 1995). The wide variation in latitude and altitude under the cloud forests exist due to the variations on relationship between the topography and environment, in particular to elevation of the mountain hills as well as distances from coast, which impact the extent as well as occurrence of mist from the ground-level ranging from 30°N to 30°S, (Jarvis and Mulligan, 2011) mainly at altitudes between 1200 m and 2800 m. The current region of largest TMCF is located in Asian countries, primarily Papua New Guinea and Indonesia, there by the America. In Asian countries the TMCF accounts only 5.9% of all tropical mountain forests (Scatena *et al*., 2010).

Tropical Cloud Forest (TMCF) of the Western Ghats, identified as shola Forest, offer a significant ecological, environmental and management perspective into international strategies for the restoration of TMCF inside a regional biodiversity hotspot. In the last century and a half, some authors have estimated that 50 percent of the shola forests have been lost (Sukumar *et al*., 1995).

2.2 SHOLA LANDSCAPE HISTORY

Till 15th century the trend in agriculture gathering and nomadic pastoralism was increasing. Thus, it resulted in the settling down of people in the Eastern and Northern parts of the Nilgiris. Significantly, during the time of British colonization a broad change in the land use pattern was observed. Between 1847 and 1950, the region under commercial vegetable crops in Nilgiris grew more than 100-fold. Thus, the shola-grassland ecosystem in the northern as well as central plateau were transformed for commercial agriculture.

Using Waste Land Rules (1863), broad land transfer (~350 ha) was made to European farmers for the cultivation of coffee, tea and cinchona plantations. By 1900, shola forests were cleared and put under cultivation in approximately 50 percent of the plateau, mainly in the eastern and central parts. With the enactment of the Madras Forest Act in 1883, British authorities took over forest property, proclaimed it as forest reserves and abolished local rights. The experimental planting of exotic tree plantations was launched in mid-1800 to meet the needs of fuelwood and wood although there was minimal conversion of grassland and natural forest to agricultural land. In 1832, Australian Wattles (*Acacia* sp.) were introduced, followed by *Eucalyptus* sp. in 1847. By 1910, the forest department had 635 hectares of exotic tree plantations and 400 ha of private plantation to meet fuelwood demands (Prabhakar, 1994).

Expanding the misuse of the shola forest for firewood was significant in this period. The British rulers in 1841 introduced a framework in which the agreement enables to fell the wood from fixed shola patches as per bidding rules. Over the last 200 years, the revolutionary transition of the Upper Nilgiris from rising grassland including shola forests fragments in swamps and folds in bottom of valley to constantly utilized work of cultivation, planting commercially, settlements and tree stands of monoculture crops must have a significant effect on ecosystem of shola forest that has to be discovered. According to the climate change, there is an immediate need to consider the impacts of landscape transition on shola ecosystems. Finally, the species ability in tropical montane forest to survive and adapt would largely depend on intensity and nature of land use system in the matrix that is surrounded (Kupfer *et al*., 2006).

2.3 TOPOGRAPHIC AND BIOCLIMATIC FACTORS OF SHOLA FOREST

The research conducted by Swarupanandan *et al*. (2001) found that the majority of species ≥1 cm dbh exhibited a height at an elevation of around 1,950 m but then declined sharply at an elevation of about 2,100 m. This distribution of the species showed that at elevations above 1,950 m asl, the tree is not the characteristic of life form. It also explains to Ranganathan (1938) view that the grasslands represent the climax of the South Indian hill stations. This view may not be tenable as the stunted types of tree life colonize the elevation as patchy shola forests while they constitute a minority, and the size range of trees is smaller, as opposed to that of lower altitudes. The study conducted by Ramkumar *et al*. (2000) stated that the woodcutting signs were observed in 85% of the shola patches in the upper Nilgiri hills of Tamil Nadu. The investigators noted that these are the indicators of the human interventions that were heavy and frequent. They also observed that wherever human interference in the shola forest is increased the invasion of exotic plant species is more pronounced.

Influence of topographic location is a significant factor in the pattern of vegetation in the shola forest suggested by Wood *et al*. (2011). Lower topographical areas have been correlated with the trees. This may have the impact of soil moisture, particularly in mild-lower altitudes areas. Valleys and local depressions are expected to be moister also least sensitive for burning. the local curvature greater significances in the high-level vegetation may indicate on impact in the hillsides along with depressions which provide sufficient soil moisture thereby enabling drainages, thereby preventing the adverse effect of frost and flash flooding on tree development. In either event, local topographical suffering of more than 2000 m was required to include grass than wood, largely due to waterlogging and freeze, identical findings were obtained for Ranganathan, 1938; Bader and Ruijten, 2008 and Fletcher *et al*., 2014. The research was undertaken by Ramesh *et al*. (2010) established a close association between temperature variability and wide-scale spread of tree species in the Western Ghats. The temperature and rainfall gradients and associations that form regional distributions of tree species throughout the entire Western Ghats often influence the structure of plant population on a specific habitat type in smaller scales, although in complex terrains.

Caner *et al*. (2007) noted that weather-related Bioclimatic predictors demonstrated the greatest association with elevation, it seems that weather is the major proximate environment generator of a trend in higher elevation mosaics, instead of rainfall.

The overall importance of related and rising temperature variables increases with rise in elevation, further relating the opinion that weather in Eravikulam and Nilgiris has a major effect on vegetation nature. Sankaran *et al*. (2005) showed the average annual rainfall has the key factor of tree cover in low-rainfall of African savannas. In a tropical shola-grasslands environment with highest average annual rainfall, an increase in significant vegetation layout predictor. In the Western Ghats in general, there is a change of nature at around 2000 m of height by all reports, across which there has a much lower incidence of trees. This, suggest a climatic impact on the development and sustainability of tropical evergreen trees (Ohsawa, 1991). The significance of the local topography suggested by Dobrowski (2011) and Lippok *et al*. (2014) indicates that the microclimate controls the distribution of vegetation throughout the shola–grassland ecosystem. Therefore, vegetation range change forecasts for these ecosystems will compensate for variability in topography as well as its relationship with evolving regional landscape and perturbation regimes.

Ohsawa (1991) noted the temperature for montane tropical trees exists at 2,500 m, with mean annual temperature of 10°C and 12°C during the coolest months. Vegetation over 2000 m has mean annual temperatures of 14.1°C during the coldest month a usual temperature of 7.1°C. Caner *et al*. (2007) estimate that temperature in the Nilgiris during the Glacial period of last was roughly 5°C lesser than the current day, with grasslands covering most areas of the hills over 1800 m. Temperature is an essential restricting factor for tree growth. Although Western Ghats mosaics throughout the tropics are far below the climatically established treeline, lower air and soil temperatures above 2000 m may restrict the development and viability for most tropical tree species (Korner, 1998; Korner and Paulsen, 2004). This is confirmed by the observation made by Mohandass and Davidar (2010) that the distribution of tree species in shola patches in Nilgiris indicated a strong turnover of around 1900 m to 2000 m, with a rise of more than 2000 m in the upper mountainous taxa and frost-resistant plants.

Tropical Montane Cloud Forest's altitudinal limits are influenced by landform contact with the atmosphere and are seen to a large degree to fit the lower and upper limits of cloud forest. Cloud and Temperature condensation loss differ with the scale and distance from the coast of a mountain range (Bruijnzeel and Proctor, 1995; Ashton, 2003). At lower altitudes, while drier air masses allow cold temperatures, high humid air condenses and higher altitudes to shape clouds. Temperature levels on small hills could be due to the "Massenerhebung" impact that helps vegetation to spread to their upslope habitats to larger hills (Scatena *et al*., 2010; Jarvis and Mulligan 2011). In comparison, thus often causes a lower degree of cloud condensation impact on smaller hills than on larger ones, contributing to reduction in the lesser altitude boundary of sholas on small independent hills (Grubb and Whitmore, 1966).

The great threats to the cloud forest are due to the environmental changes consisting of dry season and increased water intensity, along with extended alarming impact as fire and storms which may result from numerous possible improvements like the raising of cloud base and associated decrease in fog drenching, which will affect a large portion of the vegetation (Foster, 2001; Oliveira *et al*., 2014). Decreased precipitation during the dry season and enhanced occasions of ridiculous precipitation will also cause more influential water demand and changes in the makeup of the ecosystem. Increased temperatures coupled with reduced fog penetration will adversely impact shola trees and hinder their capability to cope with the upslope migration of lower elevation plants. which is supported by the after-effects of previous ones to gander on influence of environmental change on the cloud forest system (Still *et al*., 1999; Foster, 2010). Pounds *et al*. (1999) recorded the increase in number on free days of fog in the shola forest since 1970. Many significant effects may remember phenology changes that would disrupt current plant-pollinator structures much like plant-disperser structures and affect shola species' conceptional achievement. Joined impacts of increased alarming control and plant-animal network disruption will accelerate the dissemination of unusual introduced species within this environment.

2.4 IMPACTS OF MATRIX CONVERSION IN THE SHOLA-GRASSLAND ECOSYSTEM

Naturally fragmented environments like Western Ghats sholas provide rare chances to research on anthropogenic matrix change in which other forms of anthropogenic fragmentation, such as habitat destruction or partitioning, are much less confounded (Ewers and Didham, 2006). Subsequent conversion of the grassland matrix to the tea and plantations of exotic tree, especially over past 100 years is probably could disturb the (Driscoll *et al*., 2013) equilibrium dynamics and volatile ways. The results obtained from the studies by Filotas *et al*. (2014) and Messier *et al*. (2015) states that the change in the vegetational structure by the transformation of grasslands to the exotic plantation modified the successional rate in the shola forest that multifaceted nature along with vulnerability thus it created a progressively hard towards the administration meditation. Similar, degrees based on vulnerability desire on administration progress especially adaptable along with solid accentuation checking. A similar methodology should desire the forest manager to assemble selective situations such as the probability of conceivable forthcoming scenarios, present conditions, the anticipated difference in atmosphere and rate of interventions planned.

Thomas and Palmer (2007) stated that the differences in the climatic conditions on disturbed patches and the present degrees made from the intrusion by the exotic plants in shola-grassland patches, a potential result in soil-disrupting interventions would be one more system for an invasion in felled regions. Edge effects will likely be changed, particularly in areas where grassland has been turned into wattle (*Acacia mearnsii*) plantation, resulting in reduced light, lower wind pressure and enhanced forest edge moisture (Bunyan *et al*., 2012). Besides, the main exotic tree plantation crops, *Acacia mearnsii* has been identified as an offensive montane grassland invader.

The shola forest has been predominantly identified in the high altitudes of the Palani and Nilgiris, however, a large proportion of this form of the forest has been lost due to increased human activities such as agricultural extension, transformation to monoculture estates, livestock pressure and growth (Kumar, 1993). There is severe ongoing pressure on the remaining shola forests, which will result in further loss unless conservation measures are undertaken. Meher-Homji (1967) has stated that the sholas, once disturbed, can never recover because of eco-climatic factors, such as fire and frost that prevent shola species from regenerating in open areas. Ranganathan (1938) stated that the distribution of grassland vegetation is primarily under the influence of frost. The grasslands are a subclimax under the influence of fire (Champion, 1936; Bor, 1938; Bharucha and Shankarnarayan 1958; Chandrasekaran, 1962). Even 13,000 years ago in the Sandynallah region of the Nilgiris from the paleopalynological pieces of evidence of fossil pollen contents from peaty sediments thus revealed the extensive coverage of savanna plants (Vasanthy *et al*., 1980), therefore, suggesting that the grassland vegetation is a climax.

2.5 CESTRUM: A MONTANE FOREST INVASIVE

The *Cestrum* genus of the Solanaceae includes 175 recognized forms of bushes and vines. The natural habitat of this species in Central and South America. The majority of Cestrum species are found in mountainous areas above 800 m of altitude, in cloud forests and coniferous and oak forests. *Cestrum aurantiacum* is the most widespread plant because, where it grows in large quantities under natural forest cover, it tends to overtake the undergrowth with limited local regeneration beneath. It gives the illusion of being adjusted to the conditions of the rain forest in its local range in Nicaragua and Guatemala (de Rojas and D'Arcy, 1998; Cuevas-Arias *et al*., 2008; Monro, 2012). The proliferation of beautiful and often fragrant flowers of this genus are the explanation why it was introduced as an ornamental plant in several areas where it was further naturalized (Henderson, 2007; Harvey *et al*., 2012). Such organisms comprise *Cestrum parqui*, *Cestrum nocturnum*, *Cestrum auriculatum*, *Cestrum diurnum*, *Cestrum laevigatum*, *Cestrum aurantiacum* and *Cestrum elegans*. Many of these plants carry tiny seed berries that stay viable in the seed bank and are mostly spread by birds (Marambe *et al*., 2001; Geldenhuys, 2004; Gardener *et al*., 2013).

Symon (1981) notes that the *Cestrum* genus is capable of vegetative reproduction, fast-growing and it also appears to develop a thick mat which can inhibit the regeneration of many plant organisms. Also, they are considered to be drought and shade tolerant, Ability to thrive on soft soil and infiltrated a variety of environments, varying from dunes of coastal regions to savannahs, farms and enclosed forest. Many of them are very harmful to domesticate. They are also referred to as toxic weeds having low to strong invasion capacity (Nel *et al.*, 2004; Henderson, 2007). The Darjeeling Himalayas, Sri Lanka and the Western Ghats, *Cestrum elegans* and *Cestrum aurantiacum* are classified as invasive plants. Such organisms tend to exist at higher elevations, on 1500m and above 2000 m (Marambe *et al*., 2001; Moktan and Das, 2013; Sajeev *et al*., 2012), and in Nilgiris have actively invaded on natural forest areas and on the understory of tree planting (Saravanan *et al*., 2014).

2.6 VEGETATIVE STRUCTURE IN SHOLA FOREST ECOSYSTEM

Aiba *et al*. (2004) suggested that late-successional species on a montane forest in Kinabalu were shade tolerant. In the shola forest, the enormous trees of the forest inside are most likely shade tolerant and bigger sholas may be at a later successional phase of shola forest. The smaller sholas appear to be more dynamic with lower levels of dominance. Edge and light tolerant species such as *Berberis tinctoria*, *Neolistea cassia*, *Rhodomyrtus tomentosa* and *Sarococco saligna*, were common in shola patches. Therefore, small shola patches might be at earlier successional stages than larger shola patches. In the case of species composition dispersal limitation also might not operate in this ecosystem. Many species in tropical rain forests tend to be limited on dispersal, and the levels of dispersal limitation vary with dispersal mode (Dalling *et al.*, 2002; Seidler and Plotkin 2006). Gupta and Rege (1965) reported that the main reason for the degradation of many montane forests in the Ootacamund block is the improper distribution of grazing animals. The study conducted by Ramkumar *et al*. (2000) accepted this statement with searching of 120 shola patches out of 180 were affected by grazing pressure which have led to a reduction in the regeneration of shola tree species affected by grazing and this led to the degradation of shola ecosystem.

Ganeshaiah *et al*. (1997) analyzed the diversity of species assemblages of shola fragments islands and noted the disparity between the tiny and big sholas, the consequence being that the diversity of shola species assemblages declines with sholas size. The investigators collected even fewer grids from broad sholas but did not minimize the similarity between them and the small sholas observed among them. Consequently, the finding from the sample region does not seem to be a consequence of the sampling regimes, but attributable to the creation of different equilibrium states among the small sholas relative to the large sholas. The broad sholas, in reality, seem to cover towards a rising state of equilibrium. However, Johnson *et al*. (1996) propose that small fragments might not be independently species-rich relative to large fragments together, contributing to the ecosystem's spatial and functional diversity that could be essential for the entire shola ecosystem functional diversity.

Mohandass and Davidar (2010) find evidences to indicate the sholas move onto grassland by evolution, starting from the creation of frost-resistant tree species in grassland, and thereby providing appropriate condition for the development of lower mountain vegetation. An equivalent cycle of forest expansion is taking place in the subtropical shola-grasslands mosaics of Southeastern Brazil, were the fire had a significant effect in the vegetation trend is also clarified by Muller *et al*. (2012). Observations made in the atmospheric signal indicated by Ranganathan (1938) imply an altitudinal change if the forest lends help to the role of frost in restricting the forest to more than 2000 m. It is doubtful on the predominance in grasslands, noted by Sukumar *et al*. (1995) and Caner *et al*. (2007) in historical accounts and climatic reconstructions, was justified by Bor (1938) that increasing the level of disruption in this vegetation compared with lower elevations. Fire incidence in these mosaics will be lower in the last 30-40 years was analyzed by Srivastava (2001), since they are sparsely inhabited and controlled since protected areas where fire control is practiced.

Swarupanandan *et al*. (1998) examined the community development of tree-forms. In terms of succession, many of the shola forest patches are secondary. A more common level of the inconsistent shola forest has high reed-bamboo levels in it. Reed bamboos are often fire-points and suggest the event of frequent fires in past patches of the shola forest. In this way, the patchy shola forest with high levels of reed-bamboos speaks to a disclimax. The semilogarithmic graphs of the population structure correspond to a bimodal model from the findings obtained by the investigators, with the peak in the sapling level (1-10 cm dbh) and yet another maximum representation being from the unestablished seedlings (height < 50 cm). In this way, the graph varies basically from the commonly known J-shaped exponential or reverse population curve (Harper and White, 1974).

Sukumar *et al*. (1995), by means of stable-carbon analytics of peat deposits as markers of plant types C_3 and C_4, researched the floristic past of this environment in relation to climatic transition. During the glacial phase, grasslands (type C_4) predominated with low atmospheric CO_2 rates, lower mean temperature and low rainfall across the Indian subcontinent, likely during deglaciation, the expansion of C_3 plants reached a peak distribution with higher global CO_2 rates, higher temperatures and higher Indian summer monsoon precipitation. The transition in plant groups C_4 and C_3 seem to be linked to shifts in humidity and atmospheric CO_2, with lower rates of humidity and CO_2 preferring the latter category of plant, the researchers propose that climate change is going to alter the dynamic balance between forest as well as grassland by reducing the occurrence of frost coupled with improving the monsoon that would pick C_3 species. Researchers say that the oscillating climate change and human activities have changed the montane ecosystem's nature and function. There may be many reasons in the shola forest to decrease biodiversity, including historical triggers for diversity reduction. However, as forest are extended and compressed in reaction to climatic oscillation, the potential triggers claimed by Phillips and Gentry (1994) are linked to species turnover. Extinctions of animals may also be higher in areas of shola forest.

2.7 FLORISTIC COMPOSITION OF SHOLA FOREST ECOSYSTEM

Sholas consist mainly of large branched stunted trees with vigorous epiphytic growth, rarely exceeding 15 m. In order to distinguish shola from non-shola forest forms, a shola may be described as a high elevation (almost 1700 m) stunted forest with distinct features at elevations below 1700 m (Bunyan *et al*., 2012) sholas may be restricted to shola fragments surrounded by grasslands, given the varied conditions under which they are found. In the shola wood, the height of the tree decreases and the thickness and complexity of leaf increases. The key features of tropical montane trees are the vigorous development and absence of vertical stratification of epiphytes and mosses. Such areas are distinguished by the poor abundance of ecosystem services at a high degree of endemism (Bruijzneel and Hamilton, 2000). The overstorey species are mainly dominated by Rubiaceae, Oleaceae, Myrsinaceae, Myrtaceae, Symplocaceae and Lauraceae and by Acanthaceae, Fabaceae, Asteraceae and dicotyledon species in sub-story (Swarupanandan *et al*., 2001; Davidar *et al*., 2007).

A compilation of observations listed in 17 research studies revealed that 278 species of trees and shrub are present in the shola forest. Biodiversity of the forests in the Central and South-Western Ghats is examined in a fairly detailed way by Myers *et al*. (2000). These collections range from pantropical (1 species) to rather closely limited organisms only in the southern Western Ghats including 16 species of which are biogeographical distributed over this region. The Central and Southwest Ghats alone are abundant in eighty species (29 percent), with approximately 65 percent having ranges restricted to India and Sri Lanka. The Western Ghats, Sri Lanka's biodiversity hotspot are restricted to a minimum of 48 percent (134 types). Suresh and sukumar (1999) made the same finding, which suggests that an even greater portion of the sholas tree and shrub species in the southern and central sections of Western Ghats is unique to peninsular India and Sri Lanka. Most of the shola patches in shrub and tree genera having an Indo-Malayan resemblance. The largest family of plants is Lauraceae, preceded by Rubiaceae and Acanthaceae. The most specific genera are *Litsea, Symplocos, Strobilanthes,* and *Cinnamomum*. The genera *Berberis, Lonicera, Celtis, Hypericum, Rhododendron, Mahonia, Viburnum,* and *Sarcocca* also recognize distinct features of the Himalayas. Such species are present mainly on or out on the edges of the shola grassland. In addition to that Subtropical temperate evergreen dimension is expressed by genera such as *Ilex, Hedyotis, Symplocos, Daphiphyllum, Rapanea, Vaccinium, Ardisia, Rubus, Ternstroemia* and *Eurya*. The maximum endemic species are contained in the genera *Actinodaphn, Lasianthus, Hedyotis, Strobilanthes, Euonymus, Cinnamomum* and *Litsea.*

In an analysis contrasting six distinct forms of forest types, such as thorny brush, tropical evergreen, semi-evergreen, dry deciduous, moist deciduous and montane shola of western ghats by Bunyan *et al*. (2012), it was observed that sholas are present in areas with steep slopes and mountain folding. *Vitex leucoxylon*, *Syzygium cumini*, *Eugenia calophyllifolia*, *Dysoxylum malabaricum* and *Cinnamomum sulphuratum* were the most common trees encountered. The region has an annual precipitation of about five thousand meters and the average temperature is about 15°C. In the report, the density of the stands was higher at shola forest in contrast to other forest forms (446 individuals per hectare).

Mohandass *et al*. (2016) on floristic analysis in the mid-elevation ranging from 1800m to 2100m in Amaggal Reserve Forest, Western Ghats identified that Lauraceae, Rubiaceae, Euphorbiacea, Myrtaceae and Symplocacea were the main families dominated in the study area. This was assumed after finding the Family Value Index (FVI). In addition to forest structure, disturbances also influence the tree species richness and density and liana density and basal area and the disturbances led to the change in species composition. The mean species-area curve of the plots in the study area indicates that the population was skewed towards younger trees which indirectly shows that older species are disproportionally represented in the population. During the observation period the sholas are largely made up of large and small trees showed little variation in stand structure between high and mid-elevation shola forests, but higher elevation sites have larger sized trees. It is also noticed by the researchers that high diversity in species composition in mid-elevation than high elevation in sholas of the Nilgiri Mountains. Based on the FIV index Lauraceae was the most abundant family followed by the Rubiaceae. The most dominant species were encountered in the study area were *Litsea glabrata*, *Meliosma simplicifolia* and *Daphniphyllum neilgherrense*. The rarest species included *Scolpia crenata*, *Persea macrantha* and *Rododendron arboretum*. A total number of 77 tree species, 13 shrub species and 22 liana species identified from the study area shows a diverse community.

The vegetation survey was done by Madhu *et al*. (2017) of shola tree species in the afforested areas of Nilgiris, Tamil Nadu from 2005 to 2008 in which the survey data shows the species like *Michelia* spp., *Daphniphyllum* spp., *Syzygium* spp., Rhododendron spp., *Eurya* spp., *Celtis* spp., *Viburnum* spp., *Litsea* spp. and *Mappia* spp. were predominant on the higher altitude areas and trees like *Turpinia* spp., *Syzygium* spp., *Litsea* spp., *Symplocos* spp., *Vaccinium* spp., *Ligusustrum* spp., *Mappia* spp. and *Glohidion* spp. were common in the lower altitude regions of the study area. These variation in the species composition observed due to the survival and growth variation was influenced by the site characters. Poor performance of the seedling is due to the heavy biotic interference by the grazing animals and lack of resource availability.

The medicinal plants and other financially important plants in the shola forest were depicted by Paulsamy *et al*. (2007). The research region of 11 sholas was chosen in Nilgiris, Western Ghats. From the selected region, the flora has been recorded with its economic uses and present ecology position. The study result reported a total number of 131 species of which 88 species were identified as economically important and most of them are of medicinal interest. *Acmella calva*, *Achyranthes bidentate*, *Arisaema tortuosum*, *Arisaema leschenaultia*, *Asparagus fysoni*, *Gaulteria fragrantissima* and *Centella asiatica* are suggested for cultivation to satisfy the requirement and also to maintain these plants.

Phytosociological concentrate on Mannavan shola forest consisting of undisturbed and disturbed zones done by Chandrashekara *et al*. (2006) discovered that *Hydnocarpus alpine, Gomphandra coriacea* and *Isonandra stocksii* predominated trees in the undisturbed regions, while *Daphniphyllum neilgherrense* and *Symplocos cochinchinensis* predominated in the disturbed regions. *Ardisia rhombifolia, Lasianthus accuminatus* and *Strobilanthes homotropa* had controlled herb and bush networks in the undisturbed forest plots. Ultimately, they defined the disturbed aspect of the shola forest, the domination of light-demanding trees, herbs and shrubs group. Skewed GBH class propagation on trees with bad representations by the individual GBH class stands 30.1 to 90.0 cm, gives a symbol of the forest variety of small forest and poles. The Ramakrishnan Stand Quality Index in the disturbed region is above 2.0 as compared to nearly 1.0 stands in relatively undisturbed forest indicates the aggravation is strong and has a fair daily restoration cycle along these lines. Additionally, Planting of native tree species is an effective restoration program for the biodiversity and ecological functions of degraded vegetation and the shola forest in particular. Since 1850 it is evaluated that a large portion of the shola forest in the Nilgiris was destroyed and the present region under shola patches is around 4225 ha (Sukumar *et al*., 1995; Rawat *et al*., 2003). The shola forests are more extremely vulnerable to mild disturbances because the saplings of shola tree species do not regenerate in the open grasslands due to lack of tolerance to fire and frost (Jose *et al*., 1994).

The study conducted by the Zhuang and Corlett (1997) in the montane forest of Hong Kong the edge species such as *Berberis tinctoria*, *Rhododendron arboreum* and

Rhodomyrtus tomentosa occur predominantly appear to intolerant in shades along the shola edges. The analysis undertaken by Cayuela *et al*. (2006) showed that the positive outcome of forest edges on plant variety affected both the late-successional as well as the pioneering species. The reasons behind this may be associated with the period of tree species settlement (Helm *et al*., 2006). Upon the discovery of a hole in the ground, the pioneer species would usually colonize the edge of the area. Late successional species have a smaller risk of colonizing these locations, however, the growth of trees at the edge of the forest would continue. Such impacts would possibly be largely forgotten afterward. Therefore, the classification of species according to dispersal traits such as dispersal range, agents, etc. contribute to differential sensitivities to degradation (Henle *et al*., 2004).

Comparative analyses of zoning the East and South Asian hills vegetation by Ohsawa (1990, 1991) resulted that the zoning resulted from the removal of the associated altitude taxa. This phenomenon indicates the development of floristic abundance impoverishment by removing accessory taxa at ever-higher altitudes in the forests. This pattern of transition varies from that seen in temperate mountains where each region consists of different floristic elements that have opposing types and outcomes from a variety of impoverishment mechanisms, from low to higher altitudes, in both systemic and complex zones. Ashton (2003) investigated the border between the lower and upper mountain forest, and the interpretation articulated that the upper mountain structures are characterized by the similarity of taxa to and widely viewed as subspecies or species forming pairs with lowland taxa in wide genera, like, *Memecylon sps., Rhododendron sps., Elaeocarpus sps., Syzygium sps., Vaccinium sps.* and *Ilex sps.* The features of the transformation between the upper and lower mountain forest in the Asian hills also shows the decline in plant diversity and the substitution in organisms by closely associated congeners with other functional attributes and a shift in tree physiognomy and the increased abundance of bryophytes and epiphytes on trees (Frahm and Gradstein, 1991). On tropical mountains below 20°N lower mountain forest is dominated by higher trees of genera Ilex, Eurya, Rapanea and Symplocos, which are common in lowland warm temperate as well as subtropical East Asian forest, are located at 3800 m and form a substantial part of the upper montane (Ohsawa 1991;1995).

2.8 PHYSICO–CHEMICAL PROPERTIES OF SOIL IN THE SHOLA FOREST ECOSYSTEM

The grasslands are characterized by moderately shallow soils, nutrient rate is low and low water-retaining ability, which may be susceptible to grassland shola prohibition, given sholas preconditions for growth (Ranganathan, 1938; Noble, 1967). Sharma *et al*. (1990) have witnessed an expansion of organic carbon in the soil, expanding all amounts of nitrogen and available phosphorus under the grassland, forest and sterile sites in the area. Jose *et al*. (1994) led an examination that featured the grasslands are consistent state vegetation maintained by edaphic factors holds great. Furthermore, annoyances like fire and brushing could also have a job in restricting the shola forest to the secure valley.

Soil carbon alterations of different forest types in the Chinnar Wildlife Sanctuary were investigated by Sreekanth *et al.* (2013) who observed that shola forests possess maximum soil organic carbon content. The particulate organic carbon was also found to be maximum in shola forest soils. As the soil organic carbon content is strongly affected by plant productivity and litter inputs the higher soil organic carbon content is an indirect measure of higher productivity. The soil samples obtained from slopes of various angles as well as valleys were analyzed by Varghese *et al*. (2012) The soil physical and chemical properties differed across sampling sites and periods was mostly attributed to the study area's landscape and climate fluctuations. Miller *et al*. (1988) found that organic carbon correlated with slope location, and suggested that a close association exists between geophysical location and physico-chemical properties of soil. The study conducted by Chen and Yang (2000) found that the pH of the shola soil was weakly acidic due to the increased surface fallen leaves as the degradation of the leaf litter contributes to the aggregation of organic acids throughout the soil. Additionally, Berg *et al*. (1998) found that the pH in the pre-monsoon season were marginally lower than those in the post-monsoon and monsoon seasons due to the extreme temperature in the pre-monsoon season contributing to deposition of organic acid by effective microbial activity.

According to the analysis performed by Sumathi *et al*. (2010), the soil moisture level in the monsoon season was greater than the other two seasons due to monsoon rains in June-September. In the monsoon season, the percentage of phosphorous, nitrogen, organic carbon and sodium was lower. This might be due to higher plant absorption of nutrients during monsoon, or due to rainwater dilution. The examination conducted by Kennedy *et al*. (2005) dispersion of microbial soil populations is controlled by various natural elements such as moisture content, pH and organic soil matter content, etc. During the pre-monsoon period, the soil moisture content changed from 39.91 percent at the study site to 73.11 percent at the monsoon period. The findings of the Varghese *et al*. (2012) on an investigation in the shola forest showed that the load and soil dampness content of actinomycetes had a crucial negative relation. Actinomycetes prefer to dried soil than rain, so the heap has been found large in desert soil, and the overwhelming majority of them are resistant to heat. Water extraction from the soil is unfavorable for actinomycetes production (Zenova *et al*., 2007).

Costin *et al*. (1952) found in the Alpine soils a basic height in regard of the physico-synthetic properties of this soil. Jenny and Raychaudhary (1960) detailed that as rise builds, the atmosphere becomes cooler which favors aggregation as opposed to the humification of natural issues. Rajamannar and Krishnamoorthy (1978) indicated that mass thickness was diminished at higher elevation because of higher organic matter content. The most extreme water holding limit, absolute pore space and dampness equal trend with increasing elevation. Ranganathan (1938) revealed that sufficient soil moisture is a basic precondition for the development of shola particularly in districts where general ground frost happens. Great seepage is additionally similarly significant. Under good conditions, the shola can create for itself the edaphic conditions vital for its augmentation. It might be said, the shola makes its soil, a thick layer of humus in changing phases of disintegration overlying a dark soil of free surface with a high extent of natural issue. The study conducted by Vidyasagaran *et al*. (2004) revealed that the maximum moisture content, pH and EC was observed from the soil sample collected from the surface horizon and decreasing rate in a downward profile.

Elsy (1989) likewise detailed more prominent organic matter content in a high-altitude shola forest of Siruvani, Kerala. Rashmi *et al*. (1987) trying to portray the soil properties of a Nilgiri shola, the natural carbon is 5.8 % and the electrical conductivity is 233.9 µmhos/ cm. The soil is acidic with a pH of 6.22. Elsy (1989) additionally revealed the acidic idea of soil in the Siruvani shola, and further indicated that soil acridity expanded down the profile. Shukla *et al*. (1965) indicated that the surface soil contains the most elevated measures of natural carbon and nitrogen, which diminished down the profile.

Organic carbon, soil pH, relative humidity, soil moisture, phosphorus available, and total nitrogen increased from the edge of the forest into the center, while air temperature, soil temperature, and light transmittance decreased in this parallel. Different analyses have accounted for comparable after-effects of shifting microclimatic conditions (Williams-Linera, 1990; Brothers and Spingarn, 1992; Camargo and Kapos, 1995; Jose *et al*., 1996)

Materials and methods

3. MATERIALS AND METHODS

The present study entitled "Floristic and edaphic attributes of a shola forest ecosystem in Mankulam Forest Division, Kerala." was done to analyze the floristic composition, diversity, structure and physico-chemical properties of soil in the shola forest ecosystem located in Mankulam Forest Division.

3.1 LOCATION

The study area, Mankulam Forest Division lies between 10^0 0' and 10^0 10' North latitude and 76^0 50' and 77^0 0' East longitude. On the northern side, it has the Munnar forest range of Munnar territorial division, east and southern boundaries are shared with various tea estates and the western boundary runs along with the eastern boundary of the Adimaly range of Munnar division. The Mankulam Forest division has a total area of 9005.82 ha (22,253.37 acres) and it comprises of two ranges, namely Mankulam and Anakkulam (GOK, 2012).

3.2 CLIMATE

The temperature in the study area varies from 5^0C to 30^0C and the variation is mainly due to the altitude. The forests of the division receive rainfall from two distinct monsoons, namely South-West Monsoon and North-East Monsoon. The rainfall regime is identified with a heavy rainfall period alternating with a dry season with occasional rains. During the winter season, mist and frost are common in the study area (GOK, 2012).

3.3 GEOLOGY AND SOIL

Many of the rock formations in the Mankulam Forest Division have experienced various degrees of weathering and laterization. As a hilly landscape, the rate of erosion is fast and there is no scope for the creation of dense laterite caps. Since the soil is extracted from rocks due to their disintegration, decomposition and other modifications, the interaction between soil and rock cannot diverge from the climate, and soil is regarded as a result of its climate. Mankulam Forest Division has four soil types: forest loam, riverine alluvial, laterite and red loam (GOK, 2012).

3.4 VEGETATION

Based on the classification of forest types of India which was revised by Chandrasekharan (1962) and Champion and Seth (1968), four types of vegetation are seen in Mankulam Forest Division. They are;

3.4.1 West coast tropical evergreen forests (1A/C4)

This is the forest type that occurs throughout the tropical parts of Southern India where well-distributed rainfall is there. The mean annual temperature is about 27^{0}C and the annual rainfall varies from 2000 mm to 3300 mm. The number of rainy days can vary from 118 to 150 (Champion and Seth, 1968). The major portion of the Mankulam Forest Division comes under this forest type and is characterized by the luxuriant growth of evergreen trees with varying sizes arranged in a vertical mixture (GOK, 2012).

3.4.2 West coast semi-evergreen forests (2A/C2)

This type of forest is generally found in the Western Ghats between the wet evergreen and moist deciduous types only as a narrow strip (Champion and Seth, 1968). Inside the Mankulam forest division, this type of forest is generally found in the over-exploited areas and the forests near to occupied land. These are high forests with closed canopy and a heterogeneous mixture of deciduous and evergreen species with a clear dominance of evergreen species in the lower storey (GOK, 2012).

3.4.3 Grass Lands (11A/C1/DS2)

Grassland patches are occurring interspersed with patches of the shola forest ecosystem. While sholas are confined to the sheltered folds and depressions, mostly along the river stream bases in the hills, grassland occupied in the rest of the hills. The grasslands are occurring in the Mankulam forest division adjacent to the Eravikulam National Park (GOK, 2012).

3.4.4 Southern Montane Wet Temperate Forests (11A/C1)

This type of forest patches is seeing the hiller above 1500 Mts. The vegetation is evergreen in nature. The height of the tree is decreasing further as the elevation increases. The trees are rather short boled and branchy. The shola forest is occurring in the Mankulam forest division adjacent to the Eravikulam National Park (GOK, 2012).

3.4.5 Ochalandra reed brake (8A/E1)

Impenetrable thickets of reeds 4m to 6m height with scattered over wood of evergreen trees are found in this area. They are continuation of large reed forests in Edamalayar and Pooyamkutty valleys (GOK, 2012).

3.5 STUDY AREA

The study was conducted in the Pullumala camp shed region of Mankulam forest division. The Pullumala camp shed is located in the Anakkulam Range of Mankulam forest division. The Pullumala lies within the geographical range of latitudes 10 º 07’ 32” N and longitudes 76º 59’ 45” E.

3.6 ESTIMATION OF PLANT DIVERSITY

Fifty 10 m × 10 m sample plots were randomly selected after a detailed reconnaissance survey of the entire region and based on visual observations on floristic composition and density. From the main plots of 10 m x 10 m, all the trees above 10 cm girth at breast height were identified and their GBH and height were recorded using a measuring tape. Within the 10 m x 10 m plot, three 2 m x 2m plot were taken and all plants having a GBH below 10 cm were also counted and recorded. The plant species in the study area were later identified by consulting dendrologists/plant taxonomists

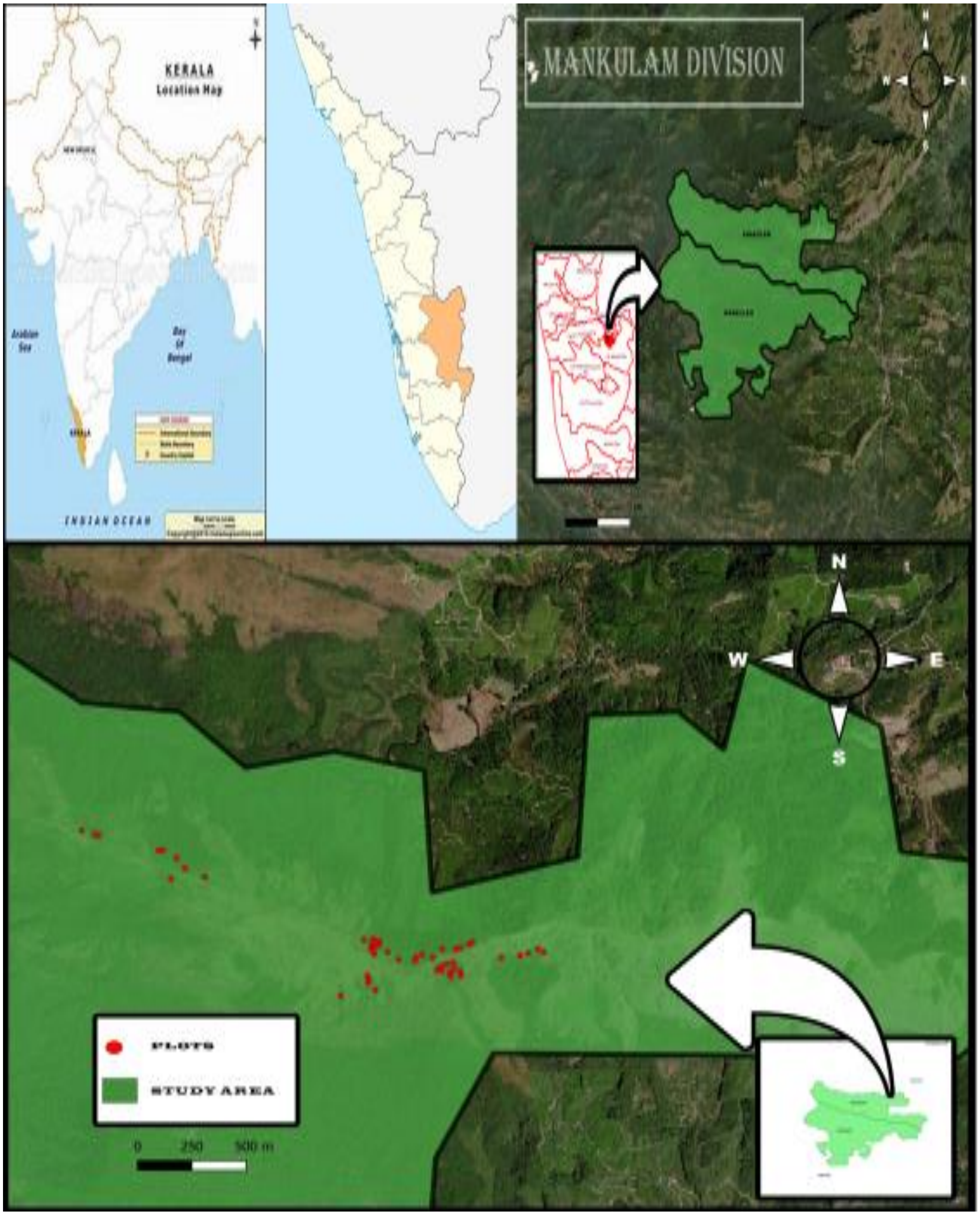

Fig. 1 Location of the study area

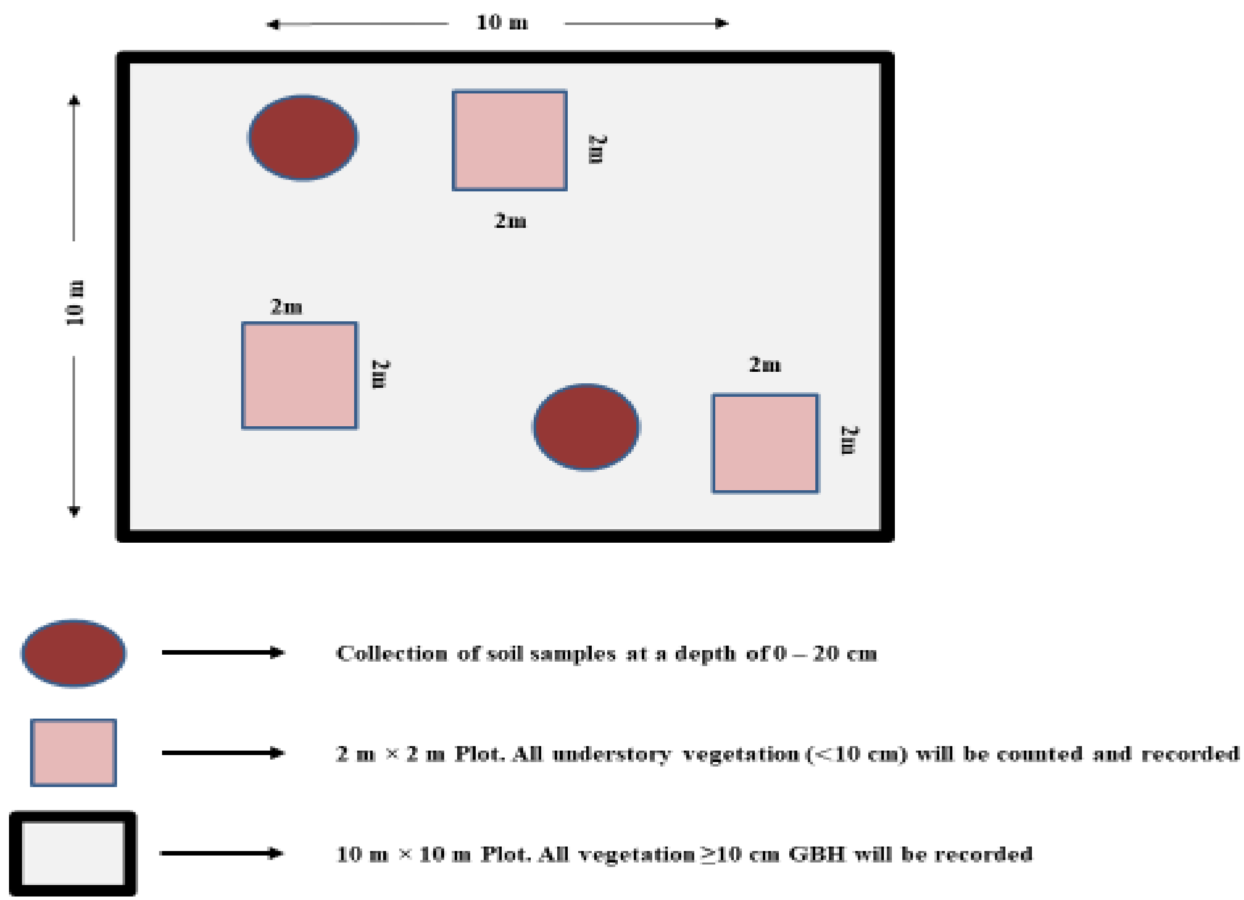

Fig. 2 Layout of the sample plot

Side view of shola forest

Interior view of shola forest

Plate 1. An overview of shola forest in Mankulam Forest division

and also, by using different software such as Kerala Trees (KFRI), Flowering plants of Kerala (KFRI), India Biodiversity portal and Western Ghats trees V.1.0 (BIOTIK) and standard floras such as Field Key to the Identification of Indigenous Arborescent Species of Kerala Forests (Balasubramanyan *et al*., 1985), Forest Trees of Kerala (Sasidharan, 2010) and A field key to the trees and lianas of evergreen forest of the Western Ghats (Pascal and Ramesh, 1987). Species names were updated with reference to The Plant List (Version 1.1, http://theplantlist.org).

3.7 PROFILE DIAGRAM

Profile diagram of the shola forest was drawn by selecting a representative strip of 80 m x 10 m stand and making a linear representation of this strip in a size to scale graph ignoring the width of the strip.

3.8 VEGETATION ANALYSIS

3.8.1 Phytosociological analysis

Frequency, density, and abundance of individual species were recorded following Curtis and McIntosh (1950) and the relative values were summed up to calculate importance value index (Phillips, 1959). Important Value Index (IVI) and Family Important Value Index (FIVI) were also calculated. The phytosociological analysis was done as given below:

Abundance of a species (As) = $\frac{Total\ number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ Quadrats\ occured\ by\ individual\ species}$

Density of a species (Ds) = $\frac{Total\ number\ of\ individuals\ of\ a\ species}{Total\ area\ of\ Quadrats\ studied}$

Frequency of a species (Fs) = $\frac{Number\ of\ quadrats\ in\ which\ a\ species\ occurs}{Total\ number\ of\ quadrats\ studied} \times 100$

Relative density of a species (RDs) = $\frac{Density (Ds) of\ a\ species}{Total\ density\ of\ all\ species} \times 100$

Relative frequency of a species (RFs) = $\frac{Frequency\ (Fs) of\ a\ species}{Sum\ of\ frequencies\ of\ all\ species} \times 100$

Relative Basal Area of a species (RBAFs) = $\frac{Total\ basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species} \times 100$

IVI of a species (IVIs) = $RDs + RFs + RBAFs$

Density of a family (D_F) = $\frac{Total\ number\ of\ individuals\ of\ a\ family}{Total\ area\ of\ Quadrats\ studied}$

Frequency of a family (F_F) = $\frac{Number\ of\ quadrats\ in\ which\ a\ family\ occurs}{Total\ number\ of\ quadrats\ studied} \times 100$

Relative density of a family (RD_F) = $\frac{Densityof\ a\ family}{Total\ density\ of\ all\ family} \times 100$

Relative frequency of a family (RF_F) = $\frac{Frequency\ of\ a\ family}{Sum\ of\ frequencies\ of\ all\ family} \times 100$

Relative Basal Area of a family ($RBAF_F$) = $\frac{Total\ basal\ area\ of\ a\ family}{Total\ basal\ area\ of\ all\ family} \times 100$

IVI of a family (FIVIs) **=** $RD_F + RF_F + RBAF_F$

3.8.2 Analysis of tree diversity

Shannon–Wiener diversity index (Shannon and Weiner, 1963), Margalef Richness Index (Margalef, 1958), Dominance was calculated using Berger parker dominance index (May, 1975) and Simpson Index (Simpson, 1949) were calculated for understanding the plant species diversity.

a) Shannon-Wiener diversity index = $\sum[pi \times \ln(pi)]$
b) Margalef Richness Index = $\sum_i[(\frac{ni}{N}\log_{10}(\frac{ni}{N})]$
c) Berger parker dominance index (d)= max(pi)
d) Simpson Diversity Index = $\frac{\sum_i n_i (n_i-1)}{N(n-1)}$

Pi = proportion of total sample represented by species i

n_i - Number of individuals of the species

N – Total number of individuals

3.8.3 Estimation of evenness

The evenness was calculated in terms of Pielou's Equitability Index (Pielou, 1969). It was done as follow:

Pielou's Equitability Index = $\frac{\Sigma_i[\frac{ni}{N}\ln(\frac{ni}{N})]}{N}$

ni - Number of individuals of the species i

N – Total number of individuals

3.8.4 Statistical analysis

a) Detrended Correspondence Analysis (DCA) was done in the species matrix to analyze the ecological distance and species assemblages using software R-Studio (version 1.3.1093)

b) Boxplot analysis was done in version 2020.1.3 of XLSTAT.

3.9 COLLECTION OF SOIL SAMPLES

From each 10 m x 10 m main plot, two random soil samples from 0-20 cm depth were collected for chemical and physical analysis.

3.10 SOIL ANALYSIS

Soil samples were analyzed for soil texture, bulk density, electrical conductivity, soil organic carbon, total nitrogen, available phosphorous, available potassium and soil pH. The analytical procedures adopted for soil analysis are given in Table. 1.

Table 1. Analytical procedures for soil analysis

Analysis	**Method**	**Reference**
pH	Potentiometry (Cyber Scan PC510, EuTech Instruments, Singapore)	FAI (2017)

Analysis	Method	References
EC	Conductometry EC-TDS Analyzer (CM 183, ElicoIndia)	FAI (2017)
Bulk Density	Undisturbed core sample	Black *et al*. (1965)
Soil texture	International pipette method	Robinson (1922)
Organic Carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
Total Nitrogen	Microkjeldahl digestion followed by distillation	Jackson (1973)
Available Phosphorous	Bray No. 1 extraction and estimation by spectrophotometer	Jackson (1973)
Available Potassium	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)

Plate 2. Photos during the analysis part carried out in the field

Results

4. RESULT

The study on phytosociology and edaphic attributes of shola forests of Mankulam Forest Division (MFD) was carried out during the period of 2019-2020. The results obtained from the study are explained below.

4.1 FLORISTIC ATTRIBUTES OF SHOLA FOREST

A total of 106 plant species were identified from this shola forest, out of which 50 species were trees, 20 shrubs, 12 herbs, 8 climbers and 16 fern species. (Fig. 3).

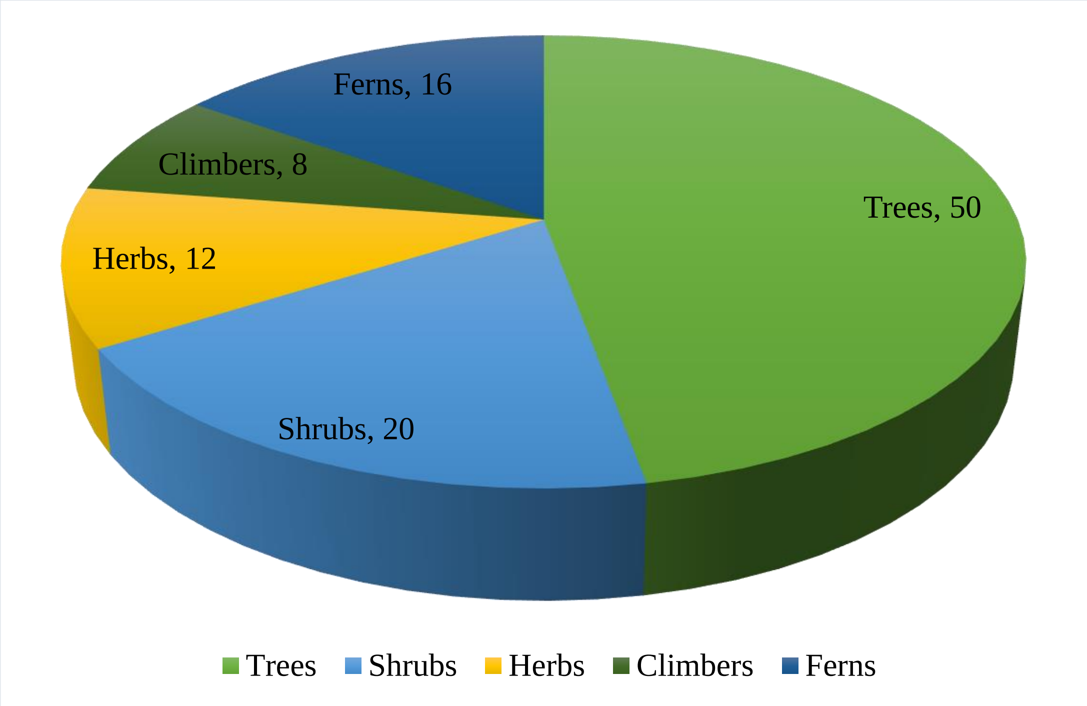

Fig. 3. Habit wise plant species (numbers) in shola forest of MFD

4.1.1 Tree species in shola forest

A total of 50 tree species were identified from shola forest (Table. 2). Lauraceae is the dominant family with 9 species, followed by Myrtaceae and Symplocaceae with 3 species each (Fig. 4).

Table 2. Tree species recorded from shola forest of MFD.

Sl. No.	**Plant species**	**Family**	**Common Name**	**IUCN status**
1	*Acronychia pedunculata* (L.) Miq.	Rutaceae	Chakkimaram, Mavaranchi, Mavuringi, Muttanari, Orilatheeppettimaram, Verukutheeni, Vettukanala, Vidukanali	LC
2	*Actinodaphne bourdillonii* Gamble	Lauraceae	Eeyoli, Malavirinji	NE
3	*Archidendron clypearia* (Jack) I.C.Nielsen	Leguminosae	Mazhavaka, Pulivaka	NE
4	*Ardisia rhomboidea* Wight	Primulaceae	NA	NE
5	*Casearia thwaitesii* Briq.	Flacourtiaceae	NA	NE
6	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Lauraceae	Elavarung, Illavangam, Karappa, Karuppa, Kuppamaram, Patta, Shanthamaram, Vayana, Vazhana, Vellakodala	NE
7	*Cinnamomum sulphuratum* Nees	Lauraceae	Kattukaruka	NE

Sl. No.	Plant species	Family	Common Name	IUCN status
8	*Clerodendrum infortunatum* L.	Verbanaceae	Paragu, Perivelam, Periyilam, Perukilam, Peruku, Peruvu, Vattapparuvalam	NE
9	*Daphniphyllum neilgherrense* (Wight)	Daphniphyllacaeae	Kozhikkulamavu, Peekkiri, Vellakottlan	NE
10	*Dodonaea viscosa* (L.) Jacq.	Sapindaceae	Aattotta, Vrali, Krali, Unnatharuvi	NE
11	*Elaeocarpus munroii* Mast.	Elaeocarpaceae		NE
12	*Elaeocarpus recurvatus* Corner	Elaeocarpaceae	Cholarudralksham, Rudraksham	VU
13	*Euonymus angulatus* Wight	Celastraceae	NA	VU
14	*Eurya nitida* Korth.	Pentaphylacaceae	Arruttuvarai, Kooramar, Kattukarana, Kattu-theyila	NE
15	*Garcinia cowa* Roxb. ex DC.	Clusiaceae	Kowa	NE
16	*Glochidion bourdillonii* Gamble	Phyllanthaceae	NA	VU

Sl. No	Plant species	Family	Common Name	IUCN status
17	*Gnidia glauca* (Fresen.) Gilg	Thymelaeaceae	Nanjinar, Nanju	NE
18	*Gomphandra coriacea* Wight	Stemonuraceae	Chottamaram, Chakkimaram, Kambilichedi	NE
19	*Gordonia obtusa* Wall. ex Wight & Arn.	Theacaeae	Adangi, Chembarasan, Karikkova, Kattukarana	NE
20	*Cinnamomum keralaense* Kosterm.	Lauraceae	Karuva	NE
21	*Ilex denticulata* Wall. ex Wight	Aquifoliaceae	NA	NE
22	*Ilex wightiana* Wall. ex Wight	Aquifoliaceae	Parasal, Vellodi	NE
23	*Ixora notoniana* Wall. ex G.Don	Rubiaceae	Iramburippi	NE
24	*Knema attenuata* (Hook. fil. & Thoms.) Warb.	Myristicaceae	Chennelli, Chorapali, Chorappathiri, Chorappayin	NE
25	*Ligustrum perrottetii* A.DC.	Oleaceae	Pinkan, Pingi, Kathikodimaram	NE
26	*Litsea bourdillonii* Gamble	Lauraceae	NA	NE
27	*Litsea wightiana* (Nees) Hook. f.	Lauraceae	Pattuthali	NE

Sl. No	Plant species	Family	Common Name	IUCN status
28	*Litsea floribunda* (Bl.) Gamble	Lauraceae	Pattuthali, Manjakudala	NE
29	*Maesa indica* (Roxb.) A. DC.	Myrsinaceae	Kireethi, Kattuvizhal, Vannathi, Vannanmaram, Vannara	NE
30	*Mahonia leschenaultii* (Wall. ex Wight & Arn.) Takeda ex Dunn	Berberidaceae	Manjanathi, Maramanjal, Mullukadambu, Mullumanjanathi	NE
31	*Meliosma pinnata* (Roxb.) Maxim.	Sabiaceae	Kalavi, Thakiri	NE
32	*Meliosma simplicifolia* (Roxb.) Walp.	Sabiaceae	Chengoini, Chenthanam, Kallavi, Kolakkatta	NE
33	*Microtropis ramiflora* Wight	Celastraceae	NA	NE
34	*Neolitsea cassia* (L.) Kosterm.	Lauraceae	Keezhambazham, Pravari, Venkana, Vellakodala	NE
35	*Neolitsea scrobiculata* Gamble	Lauraceae	Mulakunari, Shanthamaram, Vellatan	NE
36	*Nothapodytes nimmoniana* (J.Graham) Mabb.	Icacinaceae	Peenari, Pulippacha	NE

Sl. No	Plant species	Family	Common Name	IUCN status
37	*Photinia integrifolia* Lindl.	Rosaceae	Choluvan, Choluvannamaram, Kalappamaram	NE
38	*Pittosporum neelgherrense* Wight & Arn.	Pittosporaceae	Analivenga	NE
39	*Rhododendron arboreum* Sm.	Ericaceae	Alanchi, Kattupoovarasu	VU
40	*Rhodomyrtus tomentosa* (Aiton) Hassk.	Myrtaceae	Cherukotlampazham, Koratta, Kirattan, Thavattukoyya, Thaontay	NE
41	*Sapindus emarginatus* Vahl	Sapindaceae	Chuvappukamaram, Pachakotta, Pasakottamaram, Soppinkaimaram, Soapumka, Uravanchi, Urungi	NE
42	*Schefflera racemosa* (Wight) Harms	Araliaceae	Charuka, Ettilamaram, Kappamaram, Kottathunikkan	NE
43	*Symplocos obtusa* Wall.	Symplocaceae	NA	NE
44	*Symplocos cochinchinensis* (Lour.) S. Moore	Symplocaceae	Kamblivetti, Pachotti, Parala, Pambari	NE

Sl. No	Plant species	Family	Common Name	IUCN status
45	*Symplocos pendula* Wight	Symplocaceae	NA	EN
46	*Syzygium densiflorum* Wall. ex Wight & Arn.	Myrtaceae	Ayuri, Karayambuvu, Kuruthamaram, Kuruthal, Kurunjaval, Njaval, Pillanjaval	VU
47	*Syzygium lanceolatum* (Lam.) Wight & Arn.	Myrtaceae	Njaval	NE
48	*Turpinia cochinchinensis* (Lour.) Merr.	Staphyleaceae	Attuneermulla, Kanali, Kambilivetti, Pambaravetti	NE
49	*Vaccinium leschenaultii* var. leschenaultia	Vacciniceae	Kalavu, Kelamaram	NE
50	*Vernonia arborea* Buch-Ham.	Asteraceae	Eerakatthira, Karana, Kadavari, Malanperuva	NE

(LC= Least Concern, VU= Vulnerable, EN= Endangered, NE= Not Evaluated, NA= Not Available)

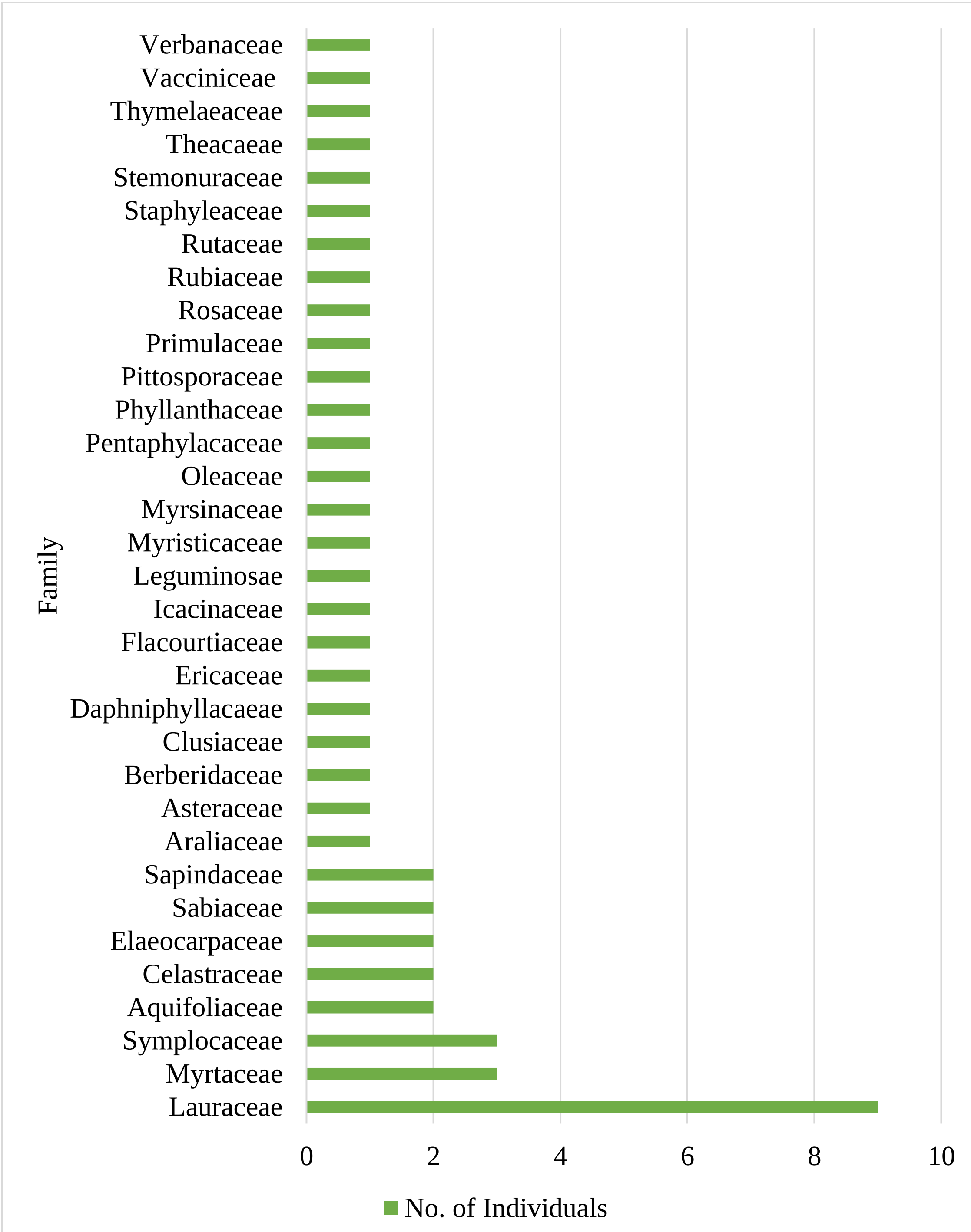

Fig. 4. Family wise tree species in shola forest of MFD

4.1.2 Shrub species in shola forest

A total of 20 shrub species were identified from shola forest (Table. 3). Rubiaceae is the dominant family with 4 species followed by Melastomataceae and Acanthaceae with 3 species each (Fig. 5).

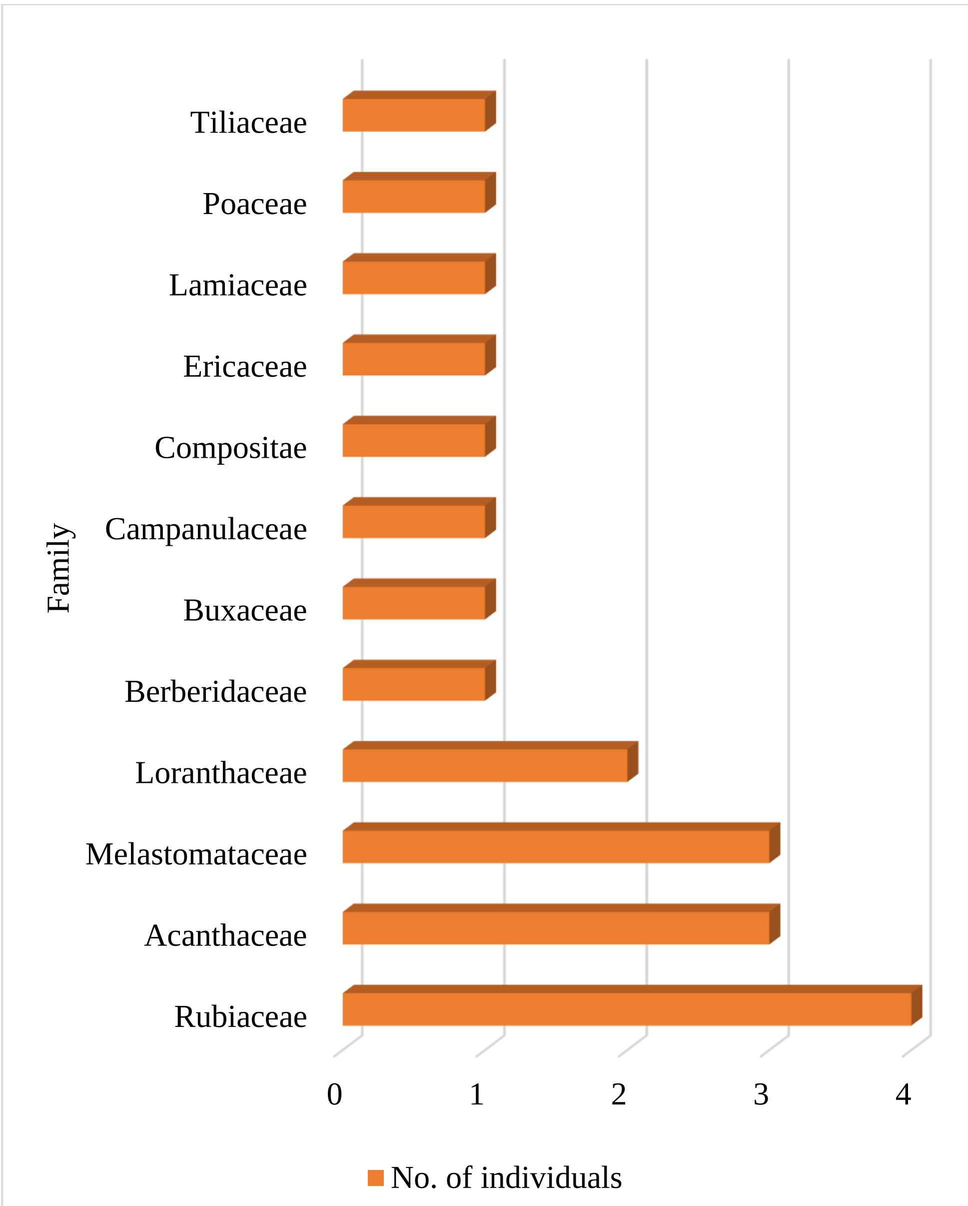

Fig. 5. Family wise shrub species in shola forest of MFD

Table 3. Shrub species recorded from shola forest of MFD.

Sl. No	Plant species	Family	Common Name	IUCN
1	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Compositae	NA	NE
2	*Arundinaria densifolia* Munro	Poaceae	NA	NE
3	*Berberis tinctoria* Lesch.	Berberidaceae	Kozhikkal-mullu	NE
4	*Gaultheria fragrantissima* Wall.	Ericaceae	Kolakkattachedi, Kolgate-chedi	NE
5	*Grewia gamblei* J.R.Drumm.	Tiliaceae	NA	EN
6	*Helixanthera obtusata* (Schult.) Danser	Loranthaceae	NA	NE
7	*Lasianthus blumeanus* Wight	Rubiaceae	NA	EN
8	*Lobelia nicotianifolia* Roth ex Roemer & Schultes	Campanulaceae	Kattupukayila	NE
9	*Macrosolen parasiticus* (L.) Danser	Loranthaceae	Chempoo	NE
10	*Medinilla malabarica* Bedd.	Melastomataceae	NA	VU
11	*Osbeckia aspera* var. *travancorica* (Bedd. ex Gamble) C.Hansen	Melastomataceae	NA	NE
12	*Osbeckia reticulata* Bedd.	Melastomataceae	NA	NE
13	*Pavetta breviflora* DC.	Rubiaceae	Malampichi	NE
14	*Pogostemon benghalensis* (Burm.f.) Kuntze	Lamiaceae	Bhoothachedayan	NE
15	*Psychotria nigra* (Gaertn.) Alston	Rubiaceae	NA	NE
16	*Psychotria nilgiriensis* var. *astephana* Deb & M.G.Gangop	Rubiaceae	Pavadakkambu	NE

Sl. No	Plant species	Family	Common Name	IUCN
17	*Sarcococca coriacea* Sweet	Buxaceae	Mattu-vadi	NE
18	*Strobilanthes luridus* Wight	Acanthaceae	Muttakannikurinji	NE
19	*Strobilanthes neoasper* Venu & P.Daniel	Acanthaceae	NA	NE
20	*Strobilanthes tristis* (Wight) T. Anders.	Acanthaceae	NA	NE

(VU= Vulnerable, NE= Not Evaluated, NA= Not Available)

4.1.3 Herb species in shola forest

A total of 12 herb species were identified from shola forest (Table 4.). In which Orchidaceae and Asteraceae is the dominant family with 2 individual species (Fig. 6.)

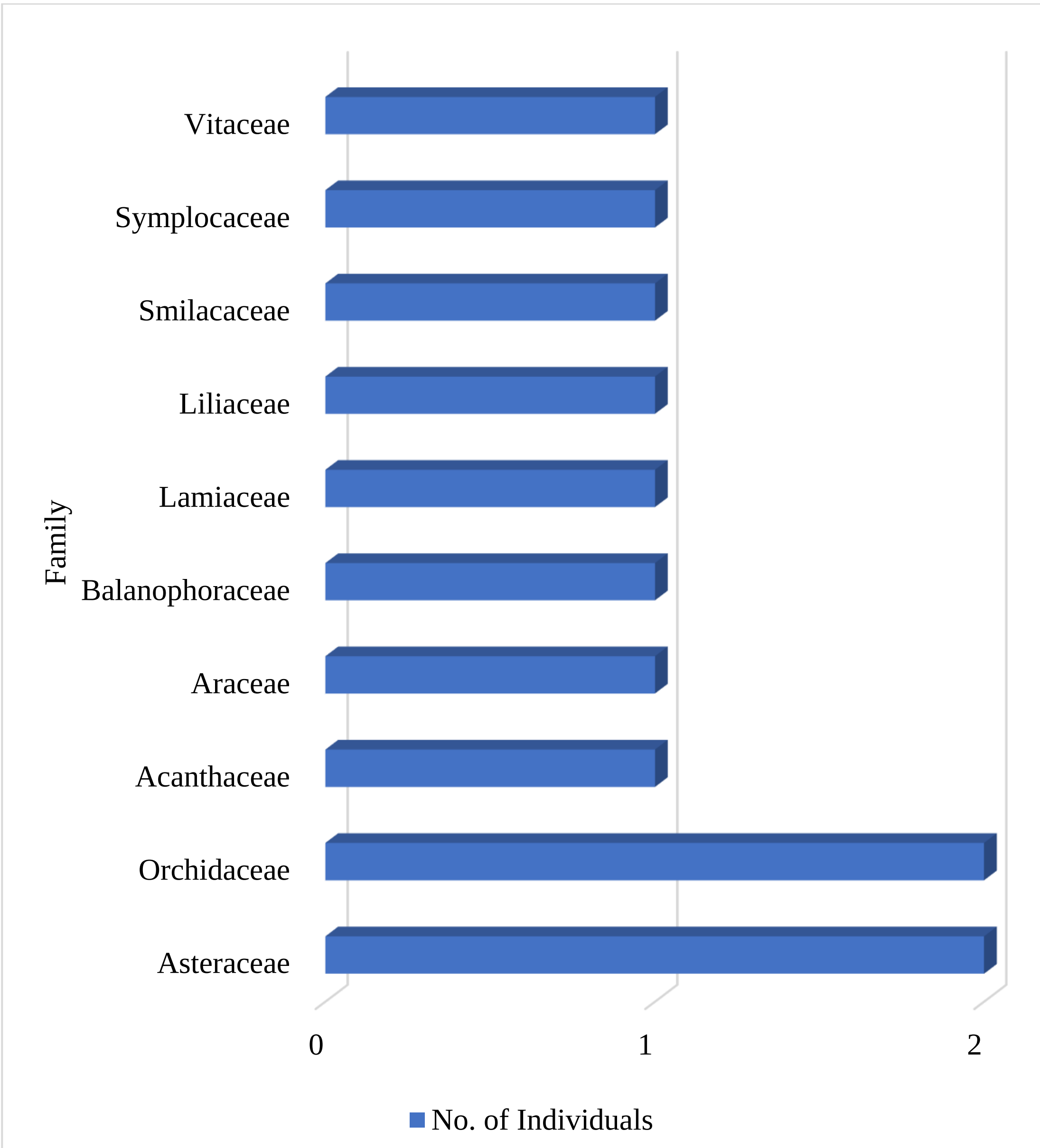

Fig. 6. Family wise herb species in shola forest of MFD

Table 4. Herb species recorded from shola forest of MFD

Sl. No	Plant species	Family	Common Name	IUCN
1	*Anaphalis meeboldii* W.W.Sm.	Asteraceae	NA	NE
2	*Arisaema leschenaultii* Blume	Araceae	Pambucholam	NE
3	*Balanophora fungosa* subsp. *indica* var. minor (Eichler) B.Hansen	Balanophoraceae	Athithippali, Kannukuttimadu, Nilamchakka	NE
4	*Brachycorythis wightii* Summerh.	Orchidaceae	NA	NE
5	*Chlorophytum indicum* (Willd. ex Schult. & Schult.f.) Dress	Liliaceae	NA	NE
6	*Erigeron karvinskianus* DC.	Asteraceae	Pottu-poovu	NE
7	*Leucas hirta* (Roth) Spreng.	Lamiaceae	NA	NE
8	*Satyrium nepalense* D.Don	Orchidaceae	NA	NE
9	*Smilax zeylanica* L.	Smilacaceae	Arikanni, Kareelanchi, Karilanchi, Keeralanchi, Valiyakanni	NE
10	*Strobilanthes lawsoni* Gamble	Acanthaceae	NA	NE
11	*Symplocos pendula* Wight	Symplocaceae	NA	NE
12	*Tetrastigma leucostaphylum* (Dennst.) Alston ex Mabb.	Vitaceae	Seenkaikkodi	NE

(NE= Not Evaluated, NA= Not Available)

4.1.2 Climber species in shola forest

A total of 8 climber species were identified from shola forest (Table. 5). Rosaceae is the dominant family with 3 species (Fig. 7.)

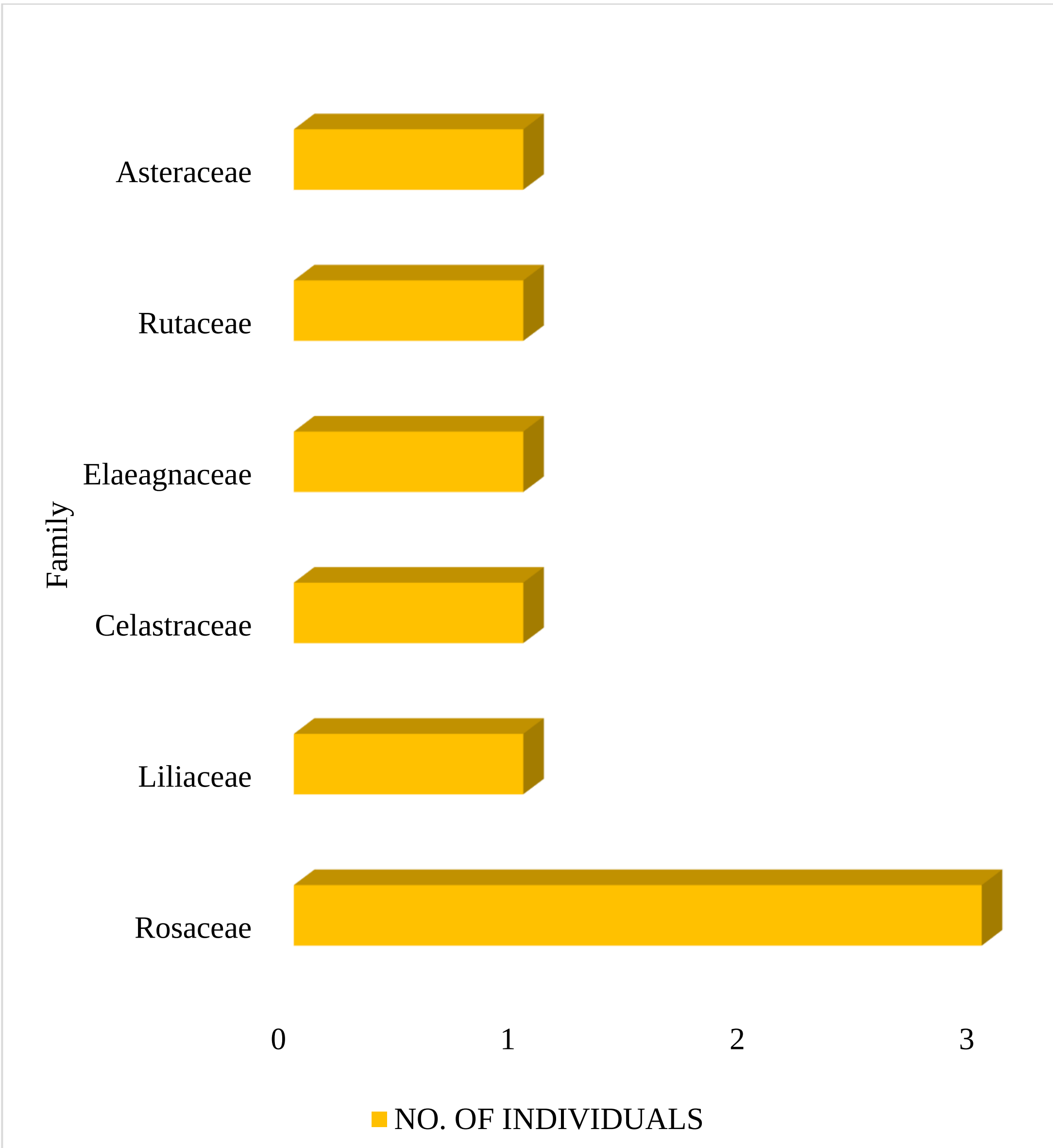

Fig. 7. Family wise Climber species in shola forest of MFD

Table. 5 Climber species recorded from shola forest of MFD.

Sl. No	Plant species	Family	Common Name	IUCN
1	*Asparagus racemosus* Willd.	Liliaceae	Chathavalli, Sathavali, Sathavari, Thalicheria, Thaliperiya, Thannivayankizhangu	NE
2	*Celastrus paniculatus* Willd.	Celastraceae	Cherupunna, Jyothishmathi, Killithinipanji, Paluzhavam, Valuzhavam	NE
3	*Elaeagnus conferta* Roxb.	Elaeagnaceae	Kattumunnthiringa, Palga	NE
4	*Rubus glomeratus* Blume	Rosaceae	Kattumunthiri, Mulluvettila	NE
5	*Rubus niveus* Thunb.	Rosaceae	Karimcheechi	NE
6	*Rubus ellipticus* Sm.	Rosaceae	Cheemullu, Mullippazham	NE
7	*Toddalia asiatica* (L.) Lam.	Rutaceae	Kanthamkolunthu, Kanthammullu, Kakkathodali, Karamullu, Melakkaranam, Mulakuthali	NE
8	*Vernonia anamallica* Bedd. ex Gamble	Asteraceae	NA	VU

(NE= Not Evaluated, NA= Not Available)

4.1.3 Fern species in shola forest

A total of 16 fern species were identified from shola forest (Table 6.). Aspleniaceae is the dominant family with 3 species (Fig. 8.)

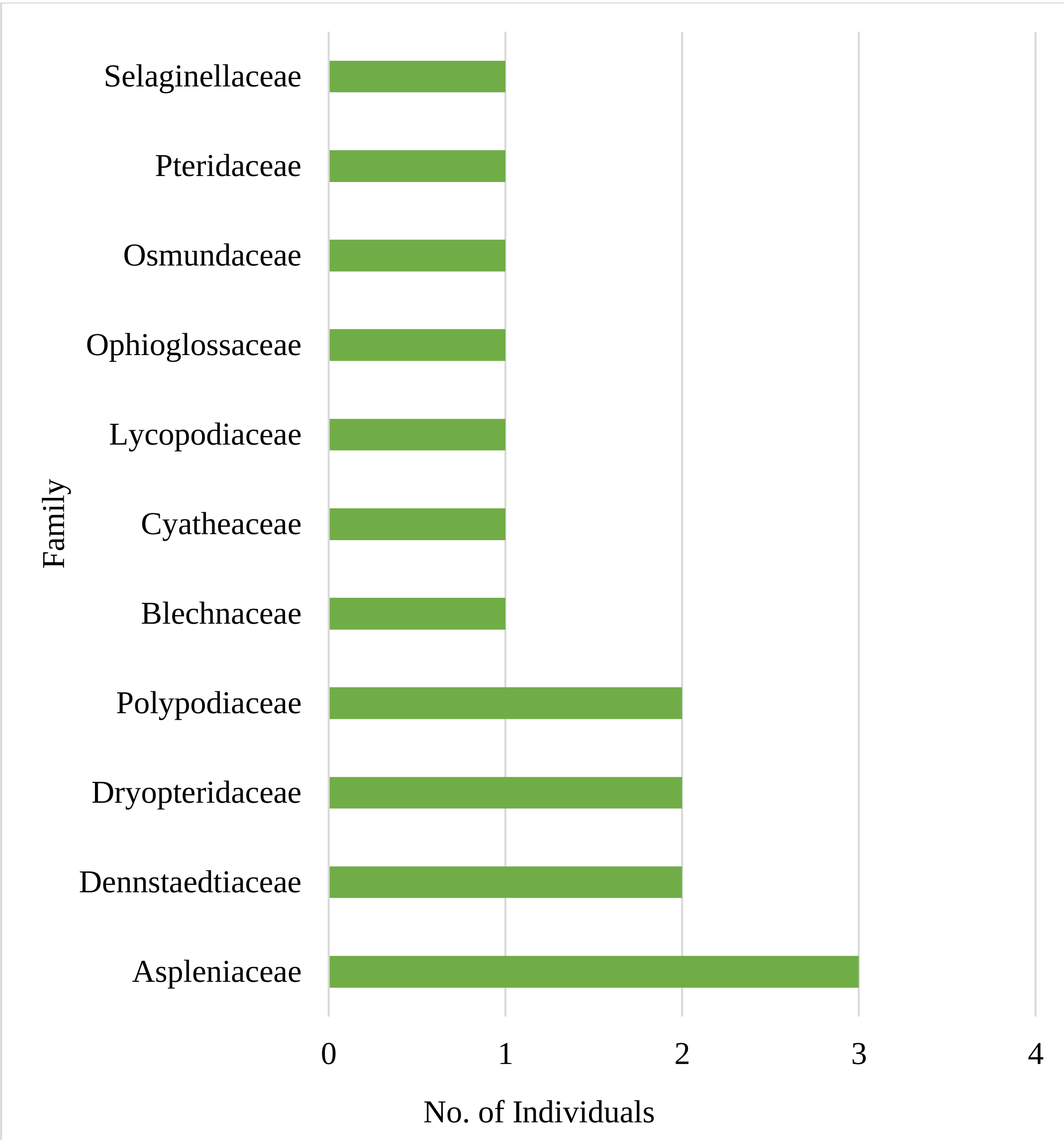

Fig. 8. Family wise Climber species in shola forest of MFD

Table 6. Fern species recorded from shola forest of MFD.

Sl. No	Plant species	Family	Common Name	IUCN
1	*Asplenium hindusthanensis* Bir	Aspleniaceae	NA	NE
2	*Asplenium tenuifolium* D. Don	Aspleniaceae	NA	NE
3	*Asplenium yoshinagae* Makino	Aspleniaceae	NA	NE
4	*Blechnum occidentale* L.	Blechnaceae	NA	NE
5	*Bolbitis asplenifolia* K. Iwats.	Dryopteridaceae	NA	NE
6	*Botrychium daucifolium* Wall. ex Hook. & Grev.	Ophioglossaceae	NA	NE
7	*Cyathea gigantea* (Wall. ex Hook.) Holttum	Cyatheaceae	NA	NE
8	*Elaphoglossum beddomei* Sledge	Dryopteridaceae	NA	NE
9	*Huperzia phlegmaria* (L.) Rothm.	Lycopodiaceae	NA	NE
10	*Microlepia strigose* (Thunb.) C. Presl	Dennstaedtiaceae	NA	NE
11	*Osmunda huegeliana* C.Presl	Osmundaceae	NA	NE
12	*Phymatosorus cuspidatus* subsp. beddomei (S.R. Ghosh) Fraser-Jenk.	Polypodiaceae	NA	NE
13	*Pteridium revolutum* (Blume) Nakai	Dennstaedtiaceae	NA	NE
14	*Pteris longipes* D. Don	Pteridaceae	NA	NE
15	*Selaginella increscentifolia* Spring	Selaginellaceae	NA	NE
16	*Selliguea montana* (Sledge) Hovenkamp	Polypodiaceae	NA	NE

(NE= Not Evaluated, NA= Not Available)

Acronychia pedunculata

Actinodaphne bourdillonii

Ageratina adenophora

Anaphalis meeboldii

Ardisia rhomboidea

Asparagus racemosus

Plate 3. Plants recorded from shola forest of Mankulam Forest Division

Asplenium hindusthanensis

Asplenium tenuifolium

Asplenium yoshinagae

Blechnum occidentale

Bolbitis asplenifolia

Botrychium daucifolium

Plate 4. Plants recorded from shola forest of Mankulam Forest Division

Casearia thwaitesii

Celastrus paniculatus

Cinnamomum malabatrum

Cinnamomum sulphuratum

Clerodendrum infortunatum

Cyathea gigantea

Plate 5. Plants recorded from shola forest of Mankulam Forest Division

Daphniphyllum neilgherrense

Dodonaea viscosa

Cinnamomum sulphuratum

Clerodendrum infortunatum

Elaeagnus conferta

Elaeocarpus munroii

Plate 6. Plants recorded from shola forest of Mankulam Forest Division

Elaeocarpus recurvatus

Elaphoglossum beddomei

Garcinia cowa

Gaultheria fragrantissima

Glochidion bourdillonii

Gnidia glauca

Plate 7. Plants recorded from shola forest of Mankulam Forest Division


Gordonia obtusa *Grewia gamblei*


Helixanthera obtusata *Huperzia phlegmaria*


Ixora notoniana *Knema attenuate*

Plate 8. Plants recorded from shola forest of Mankulam Forest Division

Litsea floribunda

Litsea wightiana

Macrosolen parasiticus

Maesa indica

Mahonia leschenaultii

Medinilla malabarica

Plate 9. Plants recorded from shola forest of Mankulam Forest Division

Meliosma pinnata

Microtropis ramiflora

Microlepia strigosa

Neolitsea cassia

Neolitsea scrobiculata

Osmunda huegeliana

Plate 10. Plants recorded from shola forest of Mankulam Forest Division

Pavetta breviflora

Phymatosorus beddomei

Pogostemon benghalensis

Psychotria nigra

Pteridium revolutum

Pteris longipes

Plate 11. Plants recorded from shola forest of Mankulam Forest Division

Psychotria nigra

Selaginella increscentifolia

Selliguea montana

Rhododendron arboretum

Rhodomyrtus tomentosa

Rubus ellipticus

Plate 12. Plants recorded from shola forest of Mankulam Forest Division

Rubus glomeratus

Rubus niveus

Sarcococca coriacea

Schefflera racemose

Smilax zeylanica

Symplocos obtusa

Plate 13. Plants recorded from shola forest of Mankulam Forest Division

Syzygium densiflorum

Syzygium lanceolatum

Tetrastigma leucostaphylum

Toddalia asiatica

Turpinia cochinchinensis

Vaccinium leschenaultia

Plate 14. Plants recorded from shola forest of Mankulam Forest Division

Vernonia anamallica

Vernonia arborea

Plate 15. Plants recorded from shola forest of Mankulam Forest Division

4.2 FLORISTIC STRUCTURE

4.2.1 Abundance, density and relative density of plant species (≥10 cm GBH)

A total of 918 (GBH > 10 cm) individuals belonging to 50 different species was recorded over a sampling area of 5000 m^2 with a density of 1836 individuals per hectare. The most Abundant species (A_S) in the study site was *Microtropis ramiflora* (2.30) followed by *Clerodendrum infortunatum* (2.14) followed by *Actinodaphne bourdillonii* and *Daphniphyllum neilgherrense* with an abundance of 2.00. The density (D_S) was calculated in per hectare and Relative Density (RD_S) of each species is shown in table 7. The highest density was occurred for *Microtropis ramiflora* with 92 individuals per hectare followed by *Dodonaea viscosa* with a density of 78 individuals per hectare. As a matter of fact, 5.01 per cent of the trees in the study area belonged to *Microtropis ramiflora*. While all other species had a relative density of less than 5 per cent. The least was occurred for *Sapindus emarginatus, Meliosma simplicifolia* and *Nothapodytes nimmoniana* with a relative density of 0.33 per cent.

4.2.2 Frequency and relative frequency of plant species (≥10 cm GBH)

The table 7 gives the frequency (F_S) and relative frequency (RF_S) of the species in which the percentage frequency was higher for the *Microtropis ramiflora* (52%) with a releative frequency of 4.55 per cent followed by *Dodonaea viscosa* and *Rhodomyrtus tomentosa* with a percentage frequency of 44 per cent and the relative frequency of 3.85 per cent followed by *Ixora notoniana Schefflera racemosa* and *Syzygium lanceolatum* with a percentage frequency of 42 per cent and the relative frequency of 3.68 per cent. The least was occured for *Sapindus emarginatus, Meliosma simplicifolia* and *Nothapodytes nimmoniana* with a percentage frequency of 6 per cent and the relative frequency was 0.53 per cent

4.2.3 Basal area and relative basal area of plant species (≥10 cm GBH)

The Basal Area (BA_S)and Relative Basal Area (RBA_S) for each species is given in Table 7. The average basal area of the stand was 22.46 m^2 ha^{-1}. The basal area was higher for *Actinodaphne bourdillonii* (6.52%) followed by *Microtropis ramiflora* (6.26%), *Syzygium densiflorum* (6.09%) and *Vaccinium leschenaultia* (5.60%) thereafter all other species has relative basal area of less than 5 per cent. The least basal area was accounted for *Sapindus emarginatus* (0.18%).

4.2.4 Importance value index of plant species (≥10 cm GBH)

Importance Value Index (IVI_S) depicted in Table 7, shows that of the 50 tree species, only ten species have importance value indices above 10.00. These species are *Microtropis ramiflora* (15.82), *Actinodaphne bourdillonii* (13.99), *Syzygium densiflorum* (12.12), *Vaccinium leschenaultia* (12.06), *Dodonaea viscosa* (11.64), *Daphniphyllum neilgherrense* (11.52), *Schefflera racemosa* (11.50), *Syzygium lanceolatum* (11.08), *Cinnamomum sulphuratum* (10.67), *Rhodomyrtus tomentosa* (10.04) and *Symplocos obtusa* (10.07). The least Important value Index value was recorded for *Meliosma simplicifolia* (1.54), *Nothapodytes nimmoniana* (1.26) and *Sapindus emarginatus* (1.04).

Table 7. Importance value index (IVI) of shola species (≥10 cm GBH) at MFD

Sl. No	Species Name	A_S	D_S	RD_S	F_S	RF_S	BA_S	RBA_S	IVI_S
1	*Acronychia pedunculata*	1.38	22	1.20	16	1.40	0.11	0.97	3.57
2	*Actinodaphne bourdillonii*	2.00	76	4.14	38	3.33	0.73	6.52	13.99
3	*Archidendron clypearia*	1.50	18	0.98	12	1.05	0.13	1.18	3.21
4	*Ardisia rhomboidea*	1.25	20	1.09	16	1.40	0.07	0.65	3.14
5	*Casearia thwaitesii*	1.17	14	0.76	12	1.05	0.06	0.57	2.39
6	*Cinnamomum keralaense*	1.80	18	0.98	10	0.88	0.07	0.66	2.52
7	*Cinnamomum malabatrum*	1.18	26	1.42	22	1.93	0.32	2.83	6.17
8	*Cinnamomum sulphuratum*	1.94	70	3.81	36	3.15	0.42	3.70	10.67
9	*Clerodendrum infortunatum*	2.14	30	1.63	14	1.23	0.12	1.03	3.89
10	*Daphniphyllum neilgherrense*	2.00	60	3.27	30	2.63	0.19	1.65	7.55
11	*Dodonaea viscosa*	1.77	78	4.25	44	3.85	0.40	3.54	11.64
12	*Elaeocarpus munroii*	1.60	16	0.87	10	0.88	0.47	4.20	5.95
13	*Elaeocarpus recurvatus*	1.75	70	3.81	40	3.50	0.28	2.45	9.76
14	*Euonymus angulatus*	1.56	50	2.72	32	2.80	0.14	1.28	6.80
15	*Eurya nitida*	1.33	16	0.87	12	1.05	0.05	0.41	2.33
16	*Garcinia cowa*	1.29	18	0.98	14	1.23	0.14	1.27	3.48
17	*Glochidion bourdillonii*	1.44	26	1.42	18	1.58	0.31	2.74	5.73

Sl. No	Species Name	As	Ds	RDs	Fs	RFs	BAs	RBAs	IVIs
18	*Gnidia glauca*	1.25	20	1.09	16	1.40	0.09	0.81	3.30
19	*Gomphandra coriacea*	1.00	12	0.65	12	1.05	0.07	0.64	2.34
20	*Gordonia obtusa*	1.69	54	2.94	32	2.80	0.39	3.51	9.25
21	*Ilex denticulata*	1.33	16	0.87	12	1.05	0.09	0.83	2.75
22	*Ilex wightiana*	1.80	18	0.98	10	0.88	0.12	1.06	2.92
23	*Ixora notoniana*	1.71	72	3.92	42	3.68	0.24	2.15	9.75
24	*Knema attenuata*	1.00	12	0.65	12	1.05	0.06	0.51	2.21
25	*Ligustrum perrottetii*	1.17	14	0.76	12	1.05	0.04	0.39	2.20
26	*Litsea bourdillonii*	1.20	12	0.65	10	0.88	0.20	1.79	3.32
27	*Litsea floribunda*	1.44	26	1.42	18	1.58	0.20	1.77	4.76
28	*Litsea wightiana*	1.78	64	3.49	36	3.15	0.29	2.58	9.22
29	*Maesa indica*	1.69	54	2.94	32	2.80	0.37	3.32	9.07
30	*Mahonia leschenaultii*	1.44	52	2.83	36	3.15	0.18	1.59	7.57
31	*Meliosma pinnata*	1.67	60	3.27	36	3.15	0.21	1.83	8.25
32	*Meliosma simplicifolia*	1.33	8	0.44	6	0.53	0.07	0.58	1.54
33	*Microtropis ramiflora*	2.30	92	5.01	52	4.55	0.70	6.26	15.82
34	*Neolitsea cassia*	1.20	12	0.65	10	0.88	0.10	0.85	2.38
35	*Neolitsea scrobiculata*	1.25	30	1.63	24	2.10	0.13	1.19	4.92

Sl. No	Species Name	As	Ds	RDs	Fs	RFs	BAs	RBAs	IVIs
36	*Nothapodytes nimmoniana*	1.00	6	0.33	6	0.53	0.05	0.41	1.26
37	*Photinia integrifolia*	1.00	12	0.65	12	1.05	0.07	0.61	2.31
38	*Pittosporum neelgherrense*	1.33	16	0.87	12	1.05	0.07	0.63	2.55
39	*Rhododendron arboreum*	1.31	68	3.70	40	3.50	0.20	1.74	8.94
40	*Rhodomyrtus tomentosa*	1.59	70	3.81	44	3.85	0.27	2.37	10.04
41	*Sapindus emarginatus*	1.00	6	0.33	6	0.53	0.02	0.18	1.04
42	*Schefflera racemosa*	1.81	76	4.14	42	3.68	0.41	3.69	11.50
43	*Symplocos obtusa*	1.89	68	3.70	36	3.15	0.36	3.22	10.07
44	*Symplocos cochinchinensis*	1.38	22	1.20	16	1.40	0.17	1.48	4.08
45	*Symplocos pendula*	1.00	10	0.54	10	0.88	0.10	0.91	2.33
46	*Syzygium densiflorum*	1.65	56	3.05	34	2.98	0.68	6.09	12.12
47	*Syzygium lanceolatum*	1.71	72	3.92	42	3.68	0.39	3.48	11.08
48	*Turpinia cochinchinensis*	1.33	16	0.87	12	1.05	0.12	1.08	3.00
49	*Vaccinium leschenaultii*	1.88	64	3.49	34	2.98	0.63	5.60	12.06
50	*Vernonia arborea*	1.50	18	0.98	12	1.05	0.13	1.20	3.23

4.2.5 Diameter frequency distribution of plant species (≥10 cm GBH)

The diameter frequency distribution is given in Table 8 and Fig. 9. The diameter frequency distribution shows an inverse 'J' shaped curve. Diameter- frequencies as percentage of the grand total are presented in Table 9 and Fig. 10. A total number of 350 individuals tree species was accounted in the GBH class of 10 cm to 20 cm. Two hundred and nineteen individual tree species were encountered in the girth class of 20 cm to 30 cm. One hundred and six tree species was identified in the GBH class of 30 cm to 40 cm. Seventy seven tree species was encountered in the GBH class of 40 cm to 50 cm. Fifty eight tree species was identified in the GBH class of 50 cm to 60 cm. Forty two tree species was encountered in the GBH class of 60 cm to 70 cm. Twenty five tree species was encountered in the GBH class of 70 cm to 80 cm. Seventeen tree species was identified in the GBH class of 80 cm to 90 cm. Ten tree species was identified in the GBH class of 90 cm to 100 cm. A total number of 14 tree species was accounted in the GBH class above 100 cm. In the GBH class of 10 cm to 20 cm the greater number of species was accounted by *Eleocarpus recurvatus* (1.85%). In the GBH class of 20 cm to 30 cm the greater number of species was accounted by *Syzygium lanceolatum* (1.42%). In the GBH class of 30 cm to 40 cm the greater number of species was accounted by *Syzygium lanceolatum* (0.87%). In the GBH class of 40 cm to 50 cm the maximum number of species was accounted by *Symplocos obtuse (*0.54%). In the GBH class of 50 cm to 60 cm the greater number of species was accounted by *Vaccinium leschenaultia* (0.98%). In the GBH of class 60 cm to 70 cm the greater number of species was accounted by *Schefflera racemosa* (0.54%). In the GBH class of 70 cm to 80 cm the greater number of species was accounted by *Dodonaea viscosa* (0.33%). Only very few species showed representation in the higher diameter classes above 100 cm. They are *Actinodaphne bourdillonii* followed by *Cinnamomum malabatrum, Cinnamomum sulphuratum, Elaeocarpus munroii*, *Gordoniaobtusa*, *Litseabourdillonii*, *Microtropisramiflora*, *Syzygium densiflorum.*

Table 8. GBH frequency distribution of plant species (≥10 cm GBH) at MFD

Sl. No	Species Name	GBH Class (cm)											
		10 - 20	**20 - 30**	**30 - 40**	**40 - 50**	**50 - 60**	**60 - 70**	**70 - 80**	**80 - 90**	**90 - 100**	**100 - 110**	**110 - 120**	**120 - 130**
1	*Acronychia pedunculata*	6	2	1	1	0	0	0	1	0	0	0	0
2	*Actinodaphne bourdillonii*	13	10	4	2	3	0	1	0	1	3	1	0
3	*Archidendron clypearia*	3	2	1	1	0	1	0	1	1	0	0	0
4	*Ardisia rhomboidei*	3	4	2	0	1	0	0	0	0	0	0	0
5	*Casearia thwaitesii*	4	2	0	0	0	0	1	0	0	0	0	0
6	*Cinnamomum keralaense*	4	2	1	1	1	0	0	0	0	0	0	0
7	*Cinnamomum malabatrum*	7	2	0	0	0	1	0	0	1	2	0	0
8	*Cinnamomum sulphuratum*	13	10	4	3	2	0	1	1	0	1	0	0
9	*Clerodendrum infortunatum*	6	4	2	2	1	0	0	0	0	0	0	0
10	*Daphniphyllum neilgherrense*	14	9	3	2	1	1	0	0	0	0	0	0
11	*Dodonaea viscosa*	16	11	3	3	2	2	2	0	0	0	0	0
12	*Elaeocarpus munroii*	1	2	0	0	0	0	0	1	1	1	1	1
13	*Elaeocarpus recurvatus*	17	11	1	2	1	2	0	1	0	0	0	0
14	*Euonymus angulatus*	15	7	0	1	1	1	0	0	0	0	0	0
15	*Eurya nitida*	4	2	1	1	0	0	0	0	0	0	0	0
16	*Garcinia cowa*	3	2	1	0	1	1	0	1	0	0	0	0
17	*Glochidion bourdillonii*	5	2	0	1	0	1	1	2	1	0	0	0

Sl. No	Species Name	GBH Class (cm)											
		10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130
18	*Gnidia glauca*	3	3	2	1	0	1	0	0	0	0	0	0
19	*Gomphandra coriacea*	2	1	1	1	0	1	0	0	0	0	0	0
20	*Gordonia obtusa*	14	4	1	2	2	1	0	1	1	1	0	0
21	*Ilex denticulata*	3	2	1	1	0	0	1	0	0	0	0	0
22	*Ilex wightiana*	3	2	1	1	0	1	1	0	0	0	0	0
23	*Ixora notoniana*	16	9	8	1	1	0	0	0	0	0	0	0
24	*Knema attenuata*	2	1	1	1	1	0	0	0	0	0	0	0
25	*Ligustrum perrottetii*	3	2	1	1	0	0	0	0	0	0	0	0
26	*Litsea bourdillonii*	2	1	0	0	0	0	1	1	0	1	0	0
27	*Litsea floribunda*	5	3	0	1	1	2	0	1	0	0	0	0
28	*Litsea wightiana*	15	8	2	2	2	2	1	0	0	0	0	0
29	*Maesa indica*	9	5	3	3	2	2	2	1	0	0	0	0
30	*Mahonia leschenaultii*	12	8	2	2	2	0	0	0	0	0	0	0
31	*Meliosma pinnata*	17	7	2	1	2	0	1	0	0	0	0	0
32	*Meliosma simplicifolia*	1	1	0	0	1	1	0	0	0	0	0	0
33	*Microtropis ramiflora*	16	9	5	3	4	5	2	1	0	0	1	0
34	*Neolitsea cassia*	4	0	0	0	1	0	0	1	0	0	0	0
35	*Neolitsea scrobiculata*	6	4	2	1	1	1	0	0	0	0	0	0
36	*Nothapodytes nimmoniana*	0	0	2	0	1	0	0	0	0	0	0	0

Sl. No	Species Name	GBH Class (cm)											
		10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130
37	*Photinia integrifolia*	3	1	0	1	0	0	1	0	0	0	0	0
38	*Pittosporum neelgherrense*	3	1	2	1	1	0	0	0	0	0	0	0
39	*Rhododendron arboreum*	14	12	6	1	1	0	0	0	0	0	0	0
40	*Rhodomyrtus tomentosa*	13	9	5	7	1	0	0	0	0	0	0	0
41	*Sapindus emarginatus*	0	2	1	0	0	0	0	0	0	0	0	0
42	*Schefflera racemose*	16	9	3	2	2	5	1	0	0	0	0	0
43	*Symplocos obtusa*	12	8	6	5	0	1	0	1	1	0	0	0
44	*Symplocos cochinchinensis*	0	0	7	2	1	0	1	0	0	0	0	0
45	*Symplocos pendula*	0	1	1	1	0	1	1	0	0	0	0	0
46	*Syzygium densiflorum*	13	2	2	1	1	0	3	2	3	0	0	1
47	*Syzygium lanceolatum*	7	13	8	3	2	1	2	0	0	0	0	0
48	*Turpinia cochinchinensis*	1	0	2	3	2	0	0	0	0	0	0	0
49	*Vaccinium leschenaultia*	0	6	4	6	9	7	0	0	0	0	0	0
50	*Vernonia arborea*	1	1	2	2	3	0	0	0	0	0	0	0

Table 9. GBH frequency as percentage distribution of plant species (≥10 cm GBH) at MFD.

Sl. No	Species Name	GBH Class (cm)											
		10 - 20	**20 - 30**	**30 - 40**	**40 - 50**	**50 - 60**	**60 - 70**	**70 - 80**	**80 - 90**	**90 - 100**	**100 - 110**	**110 - 120**	**120 - 130**
1	*Acronychia pedunculata*	0.65	0.22	0.11	0.11	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
2	*Actinodaphne bourdillonii*	1.42	1.09	0.44	0.22	0.33	0.00	0.11	0.00	0.11	0.33	0.11	0.00
3	*Archidendron clypearia*	0.33	0.22	0.11	0.11	0.00	0.11	0.00	0.11	0.11	0.00	0.00	0.00
4	*Ardisia rhomboidei*	0.33	0.44	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	*Casearia thwaitesii*	0.44	0.22	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
6	*Cinnamomum keralaense*	0.44	0.22	0.11	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	*Cinnamomum malabatrum*	0.76	0.22	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.22	0.00	0.00
8	*Cinnamomum sulphuratum*	1.42	1.09	0.44	0.33	0.22	0.00	0.11	0.11	0.00	0.11	0.00	0.00
9	*Clerodendrum infortunatum*	0.65	0.44	0.22	0.22	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	*Daphniphyllum neilgherrense*	1.53	0.98	0.33	0.22	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00
11	*Dodonaea viscosa*	1.74	1.20	0.22	0.33	0.22	0.22	0.33	0.00	0.00	0.00	0.00	0.00
12	*Elaeocarpus munroii*	0.11	0.22	0.00	0.00	0.00	0.00	0.00	0.11	0.11	0.11	0.11	0.11
13	*Elaeocarpus recurvatus*	1.85	1.20	0.11	0.22	0.11	0.22	0.00	0.11	0.00	0.00	0.00	0.00
14	*Euonymus angulatus*	1.63	0.76	0.00	0.11	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00
15	*Eurya nitida*	0.44	0.22	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	*Garcinia cowa*	0.33	0.22	0.11	0.00	0.11	0.11	0.00	0.11	0.00	0.00	0.00	0.00
17	*Glochidion bourdillonii*	0.54	0.22	0.00	0.11	0.00	0.11	0.11	0.22	0.11	0.00	0.00	0.00

Sl. No	Species Name	GBH Class (cm)											
		10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130
18	*Gnidia glauca*	0.33	0.33	0.22	0.11	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
19	*Gomphandra coriacea*	0.22	0.11	0.11	0.11	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
20	*Gordonia obtusa*	1.53	0.44	0.11	0.22	0.22	0.11	0.00	0.11	0.11	0.11	0.00	0.00
21	*Ilex denticulata*	0.33	0.22	0.11	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
22	*Ilex wightiana*	0.33	0.22	0.11	0.11	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.00
23	*Ixora notoniana*	1.74	0.98	0.87	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	*Knema attenuata*	0.22	0.11	0.11	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	*Ligustrum perrottetii*	0.33	0.22	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	*Litsea bourdillonii*	0.22	0.11	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.11	0.00	0.00
27	*Litsea floribunda*	0.54	0.33	0.00	0.11	0.11	0.22	0.00	0.11	0.00	0.00	0.00	0.00
28	*Litsea wightiana*	1.63	0.87	0.22	0.22	0.22	0.22	0.11	0.00	0.00	0.00	0.00	0.00
29	*Maesa indica*	0.98	0.54	0.33	0.33	0.22	0.22	0.22	0.11	0.00	0.00	0.00	0.00
30	*Mahonia leschenaultii*	1.31	0.87	0.22	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	*Meliosma pinnata*	1.85	0.76	0.22	0.11	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00
32	*Meliosma simplicifolia*	0.11	0.11	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00
33	*Microtropis ramiflora*	1.74	0.98	0.54	0.33	0.44	0.54	0.22	0.11	0.00	0.00	0.11	0.00
34	*Neolitsea cassia*	0.44	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00
35	*Neolitsea scrobiculata*	0.65	0.44	0.22	0.11	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00
36	*Nothapodytes nimmoniana*	0.00	0.00	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sl. No	Species Name	GBH Class (cm)											
		10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130
37	*Photinia integrifolia*	0.33	0.11	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
38	*Pittosporum neelgherrense*	0.33	0.11	0.22	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	*Rhododendron arboreum*	1.53	1.31	0.65	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	*Rhodomyrtus tomentosa*	1.42	0.98	0.54	0.76	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	*Sapindus emarginatus*	0.00	0.22	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	*Schefflera racemose*	1.74	0.98	0.33	0.22	0.22	0.54	0.11	0.00	0.00	0.00	0.00	0.00
43	*Symplocos obtusa*	1.31	0.87	0.65	0.54	0.00	0.11	0.00	0.11	0.11	0.00	0.00	0.00
44	*Symplocos cochinchinensis*	0.00	0.00	0.76	0.22	0.11	0.00	0.11	0.00	0.00	0.00	0.00	0.00
45	*Symplocos pendula*	0.00	0.11	0.11	0.11	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.00
46	*Syzygium densiflorum*	1.42	0.22	0.22	0.11	0.11	0.00	0.33	0.22	0.33	0.00	0.00	0.11
47	*Syzygium lanceolatum*	0.76	1.42	0.87	0.33	0.22	0.11	0.22	0.00	0.00	0.00	0.00	0.00
48	*Turpinia cochinchinensis*	0.11	0.00	0.22	0.33	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	*Vaccinium leschenaultia*	0.00	0.65	0.44	0.65	0.98	0.76	0.00	0.00	0.00	0.00	0.00	0.00
50	*Vernonia arborea*	0.11	0.11	0.22	0.22	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00

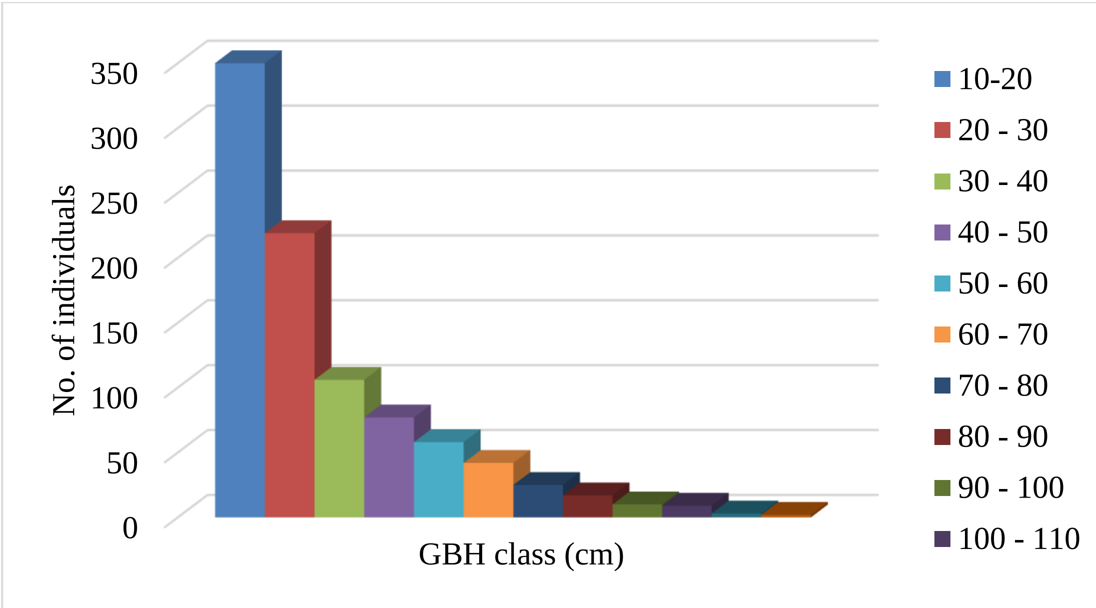

Fig. 9. GBH frequency distribution of plant species (≥10 cm GBH) at MFD

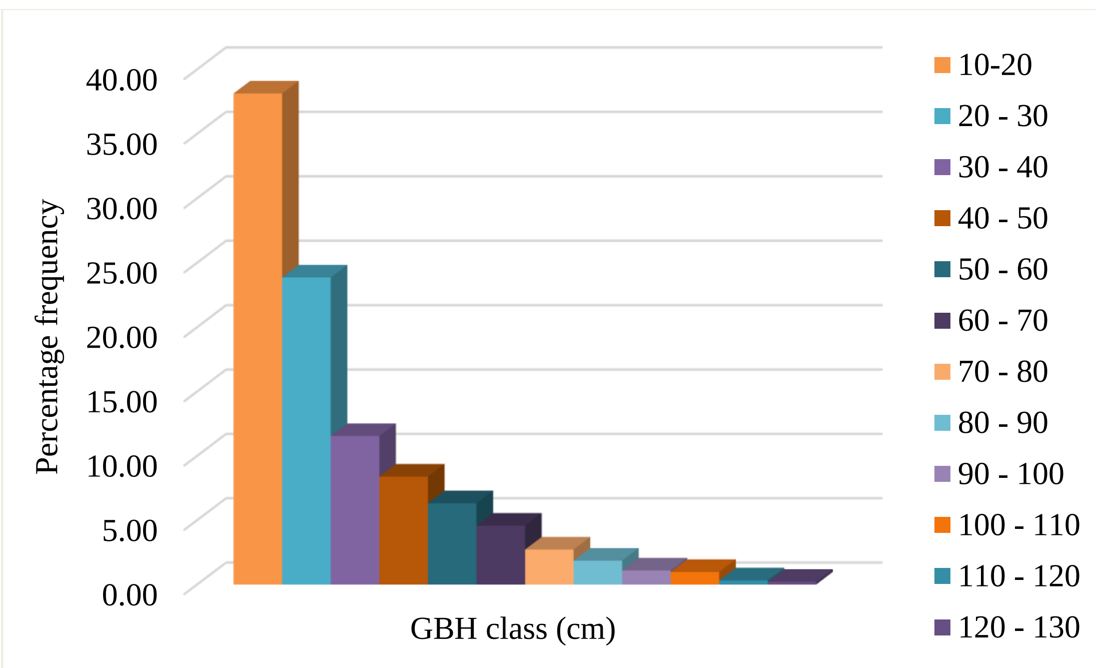

Fig. 10. GBH frequency as percentage distribution of plant species (≥10 cm GBH) at MFD

4.2.6 Height frequency distribution of plant species (≥10 cm GBH)

The height frequency distribution of various height-classes is given in Table 10 and Fig. 11. The height frequency distribution also shows an inverse 'J' shape pattern. Height-frequencies as percentage of the grand total are presented in Table 11 and Fig. 12. A total number of 458 tree species was accounted in the height class of 1.5 m to 4 m. Three hundred and twenty-four tree species were encountered in the height class of 4.1 m to 6.5 m. One hundred and six tree species were encountered in the height class of 6.6 m to 9 m. Only 30 trees accounted in the height class of above 9 m. In the height class 1.5 m to 4 m the greater number of species was accounted by *Rhodomyrtus tomentosa* with 2.83%. In the height class 4.1 m to 6.5 m the greater number of species was accounted by *Vaccinium leschenaultii* with 1.96%. In the height class 6.6 m to 9 m the greater number of species was accounted by *Syzygium densiflorum* with 1.53%. In the height class 9.1 m to 11.5 m the greater number of species was accounted by *Syzygium densiflorum* with 0.44%. In height class 11.6 m to 14 m *Actinodaphne bourdillonii* and *Elaeocarpus munroii* accounts 0.22% each. Only few species showed representation in the height classes of above 11.6 m. They are *Actinodaphne bourdillonii*, *Cinnamomum malabatrum*, *Elaeocarpus munroii*, *Gordonia obtusa*, *Microtropis ramiflora*, *Syzygium densiflorum*.

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Table 10. Height frequency distribution of plant species (≥10 cm GBH) at MFD.

Sl. No.	Species Name	Height class (m)				
		1.5-4.0	4.1-6.5	6.6-9.0	9.1-11.5	11.6-14.0
1	*Acronychia pedunculata*	7	2	2	0	0
2	*Actinodaphne bourdillonii*	22	7	5	2	2
3	*Archidendron clypearia*	5	2	2	0	0
4	*Ardisia rhomboidei*	6	3	1	0	0
5	*Casearia thwaitesii*	4	2	0	1	0
6	*Cinnamomum keralaense*	4	2	2	1	0
7	*Cinnamomum malabatrum*	6	3	2	1	1
8	*Cinnamomum sulphuratum*	11	16	6	2	0
9	*Clerodendrum infortunatum*	7	6	2	0	0
10	*Daphniphyllum neilgherrense*	16	14	0	0	0
11	*Dodonaea viscosa*	22	17	0	0	0
12	*Elaeocarpus munroii*	1	2	1	2	2
13	*Elaeocarpus recurvatus*	16	13	6	0	0
14	*Euonymus angulatus*	17	7	1	0	0
15	*Eurya nitida*	4	4	0	0	0
16	*Garcinia cowa*	4	2	3	0	0
17	*Glochidion bourdillonii*	6	4	2	1	0

Sl. No.	Species Name	Height class (m)				
		1.5-4.0	4.1-6.5	6.6-9.0	9.1-11.5	11.6-14.0
18	*Gnidia glauca*	8	2	0	0	0
19	*Gomphandra coriacea*	2	3	1	0	0
20	*Gordonia obtuse*	14	9	2	1	1
21	*Ilex denticulata*	3	4	1	0	0
22	*Ilex wightiana*	4	3	2	0	0
23	*Ixora notoniana*	19	15	2	0	0
24	*Knema attenuate*	3	3	0	0	0
25	*Ligustrum perrottetii*	4	2	1	0	0
26	*Litsea bourdillonii*	3	1	1	1	0
27	*Litsea floribunda*	8	2	3	0	0
28	*Litsea wightiana*	17	13	2	0	0
29	*Maesa indica*	12	9	6	0	0
30	*Mahonia leschenaultii*	14	12	0	0	0
31	*Meliosma pinnata*	18	9	3	0	0
32	*Meliosma simplicifolia*	2	1	1	0	0
33	*Microtropis ramiflora*	16	17	8	4	1
34	*Neolitsea cassia*	3	1	1	1	0
35	*Neolitsea scrobiculata*	7	6	2	0	0
36	*Nothapodytes nimmoniana*	1	2	0	0	0
37	*Photinia integrifolia*	5	1	0	0	0

Sl. No.	Species Name	Height class (m)				
		1.5-4.0	**4.1-6.5**	**6.6-9.0**	**9.1-11.5**	**11.6-14.0**
38	*Pittosporum neelgherrense*	3	4	1	0	0
39	*Rhododendron arboreum*	21	10	3	0	0
40	*Rhodomyrtus tomentosa*	26	8	1	0	0
41	*Sapindus emarginatus*	2	1	0	0	0
42	*Schefflera racemose*	19	14	5	0	0
43	*Symplocos obtuse*	20	13	1	0	0
44	*Symplocos cochinchinensis*	5	5	1	0	0
45	*Symplocos pendula*	2	2	1	0	0
46	*Syzygium densiflorum*	3	6	14	4	1
47	*Syzygium lanceolatum*	22	10	3	1	0
48	*Turpinia cochinchinensis*	3	5	0	0	0
49	*Vaccinium leschenaultia*	9	18	5	0	0
50	*Vernonia arborea*	2	7	0	0	0

Table 11. Height frequency as percentage distribution of plant species (≥10 cm GBH) at MFD.

Sl. No.	Species Name	Height class (m)				
		1.5-4.0	**4.1-6.5**	**6.6-9.0**	**9.1-11.5**	**11.6-14.0**
1	*Acronychia pedunculata*	0.76	0.22	0.22	0.00	0.00
2	*Actinodaphne bourdillonii*	2.40	0.76	0.54	0.22	0.22
3	*Archidendron clypearia*	0.54	0.22	0.22	0.00	0.00
4	*Ardisia rhomboidei*	0.65	0.33	0.11	0.00	0.00
5	*Casearia thwaitesii*	0.44	0.22	0.00	0.11	0.00
6	*Cinnamomum keralaense*	0.44	0.22	0.22	0.11	0.00
7	*Cinnamomum malabatrum*	0.65	0.33	0.22	0.11	0.11
8	*Cinnamomum sulphuratum*	1.20	1.74	0.65	0.22	0.00
9	*Clerodendrum infortunatum*	0.76	0.65	0.22	0.00	0.00
10	*Daphniphyllum neilgherrense*	1.74	1.53	0.00	0.00	0.00
11	*Dodonaea viscosa*	2.40	1.85	0.33	0.00	0.00
12	*Elaeocarpus munroii*	0.11	0.22	0.11	0.22	0.22
13	*Elaeocarpus recurvatus*	1.74	1.42	0.65	0.00	0.00
14	*Euonymus angulatus*	1.85	0.76	0.11	0.00	0.00
15	*Eurya nitida*	0.44	0.44	0.00	0.00	0.00
16	*Garcinia cowa*	0.44	0.22	0.33	0.00	0.00
17	*Glochidion bourdillonii*	0.65	0.44	0.22	0.11	0.00

Sl. No.	Species Name	Height class (m)				
		1.5-4.0	4.1-6.5	6.6-9.0	9.1-11.5	11.6-14.0
18	*Gnidia glauca*	0.87	0.22	0.00	0.00	0.00
19	*Gomphandra coriacea*	0.22	0.33	0.11	0.00	0.00
20	*Gordonia obtuse*	1.53	0.98	0.22	0.11	0.11
21	*Ilex denticulate*	0.33	0.44	0.11	0.00	0.00
22	*Ilex wightiana*	0.44	0.33	0.22	0.00	0.00
23	*Ixora notoniana*	2.07	1.63	0.22	0.00	0.00
24	*Knema attenuate*	0.33	0.33	0.00	0.00	0.00
25	*Ligustrum perrottetii*	0.44	0.22	0.11	0.00	0.00
26	*Litsea bourdillonii*	0.33	0.11	0.11	0.11	0.00
27	*Litsea floribunda*	0.87	0.22	0.33	0.00	0.00
28	*Litsea wightiana*	1.85	1.42	0.22	0.00	0.00
29	*Maesa indica*	1.31	0.98	0.65	0.00	0.00
30	*Mahonia leschenaultii*	1.53	1.31	0.00	0.00	0.00
31	*Meliosma pinnata*	1.96	0.98	0.33	0.00	0.00
32	*Meliosma simplicifolia*	0.22	0.11	0.11	0.00	0.00
33	*Microtropis ramiflora*	1.74	1.85	0.87	0.44	0.11
34	*Neolitsea cassia*	0.33	0.11	0.11	0.11	0.00
35	*Neolitsea scrobiculata*	0.76	0.65	0.22	0.00	0.00
36	*Nothapodytes nimmoniana*	0.11	0.22	0.00	0.00	0.00
37	*Photinia integrifolia*	0.54	0.11	0.00	0.00	0.00

Sl. No.	Species Name	Height class (m)				
		1.5-4.0	4.1-6.5	6.6-9.0	9.1-11.5	11.6-14.0
38	*Pittosporum neelgherrense*	0.33	0.44	0.11	0.00	0.00
39	*Rhododendron arboreum*	2.29	1.09	0.33	0.00	0.00
40	*Rhodomyrtus tomentosa*	2.83	0.87	0.11	0.00	0.00
41	*Sapindus emarginatus*	0.22	0.11	0.00	0.00	0.00
42	*Schefflera racemose*	2.07	1.53	0.54	0.00	0.00
43	*Symplocos obtuse*	2.18	1.42	0.11	0.00	0.00
44	*Symplocos cochinchinensis*	0.54	0.54	0.11	0.00	0.00
45	*Symplocos pendula*	0.22	0.22	0.11	0.00	0.00
46	*Syzygium densiflorum*	0.33	0.65	1.53	0.44	0.11
47	*Syzygium lanceolatum*	2.40	1.09	0.33	0.11	0.00
48	*Turpinia cochinchinensis*	0.33	0.54	0.00	0.00	0.00
49	*Vaccinium leschenaultia*	0.98	1.96	0.54	0.00	0.00
50	*Vernonia arborea*	0.22	0.76	0.00	0.00	0.00

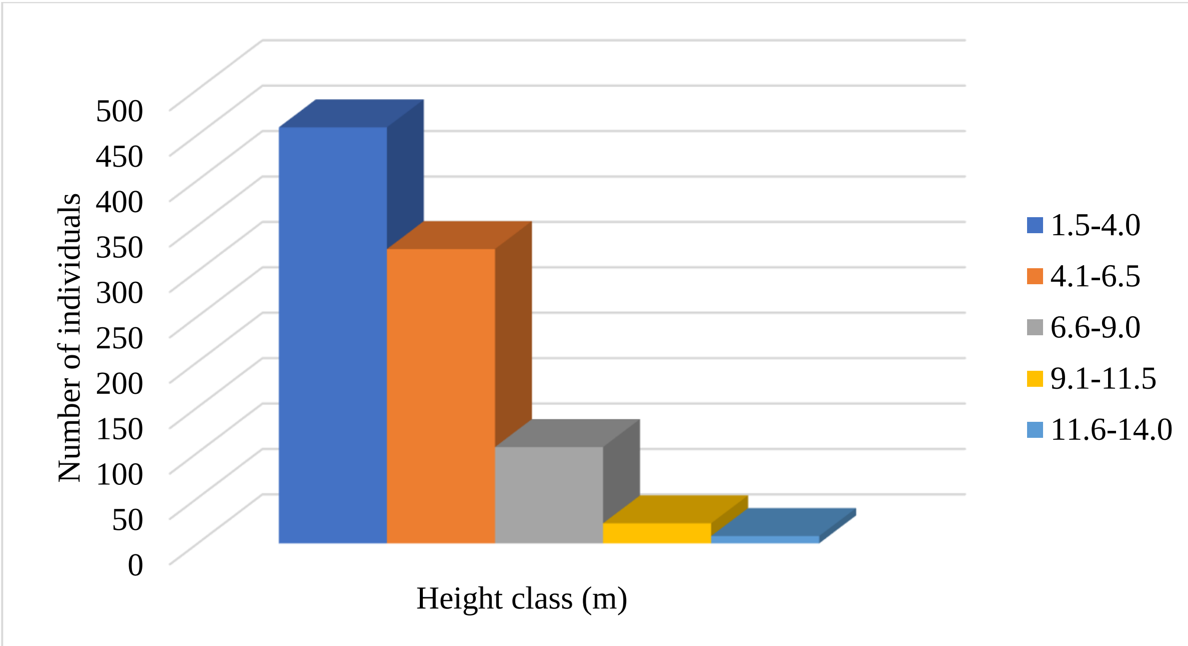

Fig. 11. Height frequency distribution of plant species (≥10 cm GBH) at MFD

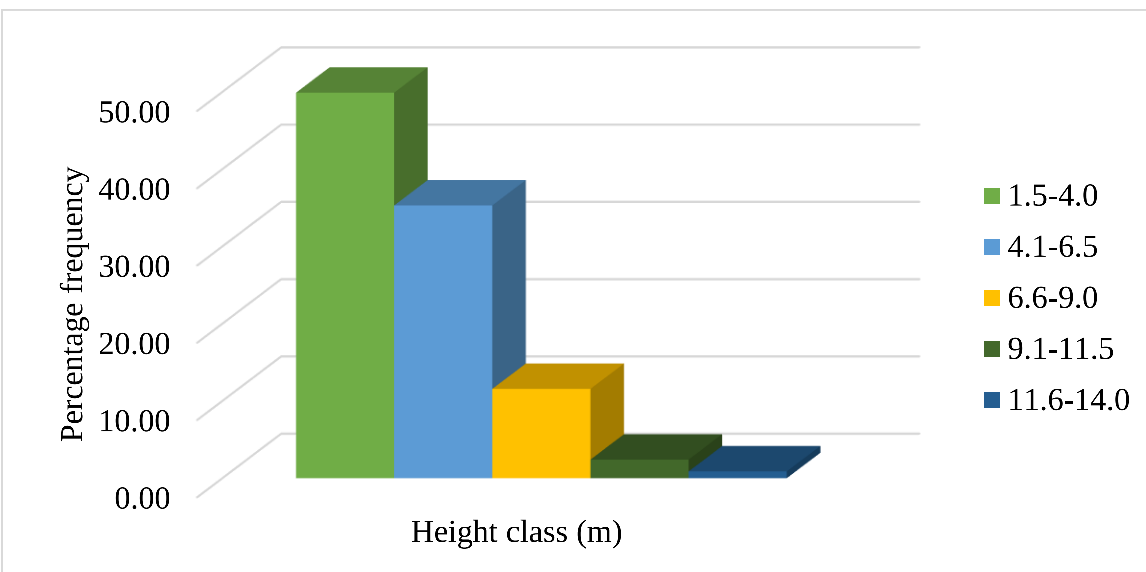

Fig. 12. Height frequency as percentage distribution of plant species (≥10 cm GBH) at MFD

4.2.8 Density and Relative Density of plant species (<10 cm GBH)

A total of 2353 (GBH <10 cm) individuals belonging to 75 different species was recorded over a sampling area of 5000 m^2 with a density of 39217 individuals per hectare. The density (D_S) and relative density (RD_S) of each species is shown in Table 12. Among the species, *Strobilanthes luridus* has the highest density with 8900 individuals per hectare followed by *Ageratina adenophora* with a density of 5350 individuals per hectare. As a matter of fact, 22.69 per cent of the plant species in the study area belonged to *Strobilanthes luridus, w*hile all other species had a relative density of less than 20 per cent of it.

4.2.9 Abundance, percentage frequency and relative frequency of plant species (<10 cm GBH)

Table 12. depicts abundance (A_S), frequency (F_S) and relative frequency (RF_S) of all species (<10 cm GBH) present on the study site. *Strobilanthes luridus* had the highest abundance with an average of 6.43 individuals per quadrat. The other species with high abundance (over 3 individuals Quadrat) were *Ageratina adenophora. Strobilanthes neoasper* and *Strobilanthes lawsoni*. *Strobilanthes luridus* was observed in 55.33 per cent of the quadrats, while 39.33 per cent of the quadrats had the species *Ageratina adenophora* and 30.67 per cent had *Strobilanthes lawsoni*

4.2.10 Importance value index of plant species (<10 cm GBH).

Importance value index (IVI_S) depicted in Table 12, shows that of the 75 plant species <10 cm GBH, only four species have importance value indices above 10.00. These species are *Strobilanthes luridus* (32.11), *Ageratina adenophora* (20.34), *Strobilanthes lawsoni* (11.94), *Strobilanthes neoasper* (10.22). The most species belonging to the Importance value index was in the Habit of shrub. The important species of less than 10 cm GBH in the habit of trees are *Dodonaea* viscosa (5.49) followed by *Rhodomyrtus tomentosa* (4.88) followed by *Actinodaphne bourdillonii* (4.47).

Table 12. Importance value index of plant species **(**<10 cm GBH)

Sl. No	Species Name	Habit	As	Fs	RFs	Ds	RDs	IVIs
1	*Actinodaphne bourdillonii*	Tree	2.33	14.00	2.38	816.67	2.08	4.47
2	*Ageratina adenophora*	shrub	5.44	55.33	6.70	5350.00	13.64	20.34
3	*Anaphalis meeboldii*	Herb	1.17	39.33	1.36	233.33	0.59	1.96
4	*Arisaema leschenaultii*	Herb	1.31	30.67	1.48	283.33	0.72	2.20
5	*Arundinaria densifolia*	Shrub	1.00	25.33	0.23	33.33	0.08	0.31
6	*Asparagus racemosus*	Climber	1.00	23.33	0.34	50.00	0.13	0.47
7	*Asplenium hindusthanensis*	Fern	1.00	18.00	0.11	16.67	0.04	0.16
8	*Asplenium tenuifolium*	Fern	1.00	16.67	0.11	16.67	0.04	0.16
9	*Asplenium yoshinagae*	Fern	1.00	16.00	0.11	16.67	0.04	0.16
10	*Balanophora fungosa*	Herb	1.10	15.33	1.14	183.33	0.47	1.60
11	*Berberis tinctoria*	Shrub	1.63	13.33	0.91	216.67	0.55	1.46
12	*Blechnum occidentale*	Fern	1.00	13.33	0.11	16.67	0.04	0.16
13	*Bolbitis asplenifolia*	Fern	1.00	12.67	0.11	16.67	0.04	0.16
14	*Botrychium daucifolium*	Fern	1.00	12.00	0.11	16.67	0.04	0.16
15	*Brachycorythis wightii*	Herb	1.42	12.00	1.36	283.33	0.72	2.08
16	*Celastrus paniculatus*	Climber	1.00	11.33	0.23	33.33	0.08	0.31
17	*Chlorophytum indicum*	Herb	1.14	10.67	0.79	133.33	0.34	1.13

Sl. No	Species Name	Habit	As	Fs	RFs	Ds	RDs	IVIs
18	*Cinnamomum keralaense*	Tree	2.33	10.67	0.34	116.67	0.30	0.64
19	*Cinnamomum sulphuratum*	Tree	2.06	10.67	1.82	550.00	1.40	3.22
20	*Clerodendrum infortunatum*	Tree	2.36	10.00	1.25	433.33	1.10	2.35
21	*Cyathea gigantea*	Fern	1.00	9.33	0.11	16.67	0.04	0.16
22	*Daphniphyllum neilgherrense*	Tree	1.70	9.33	1.14	283.33	0.72	1.86
23	*Dodonaea viscosa*	Tree	2.71	8.67	2.72	1083.33	2.76	5.49
24	*Elaeagnus conferta*	Climber	1.50	8.67	2.27	500.00	1.27	3.55
25	*Elaeocarpus munroii*	Tree	2.20	8.67	0.57	183.33	0.47	1.03
26	*Elaeocarpus recurvatus*	Tree	1.64	8.00	1.59	383.33	0.98	2.57
27	*Elaphoglossum beddomei*	Fern	1.00	8.00	0.11	16.67	0.04	0.16
28	*Erigeron karvinskianus*	Herb	2.00	8.00	0.91	266.67	0.68	1.59
29	*Gaultheria fragrantissima*	Shrub	1.33	8.00	0.68	133.33	0.34	1.02
30	*Gordonia obtusa*	Tree	2.63	7.33	1.82	700.00	1.78	3.60
31	*Grewia gamblei*	Shrub	2.00	6.67	0.91	266.67	0.68	1.59
32	*Helixanthera obtusata*	Shrub	1.43	6.67	1.59	333.33	0.85	2.44
33	*Huperzia phlegmaria*	Fern	1.00	6.67	0.11	16.67	0.04	0.16
34	*Lasianthus blumeanus*	Shrub	1.59	6.00	3.06	716.67	1.83	4.89
35	*Leucas hirta*	Herb	1.44	6.00	1.82	383.33	0.98	2.79

Sl. No	Species Name	Habit	As	Fs	RFs	Ds	RDs	IVIs
36	*Litsea wightiana*	Tree	2.65	6.00	1.93	750.00	1.91	3.84
37	*Lobelia nicotianifolia*	Shrub	1.78	6.00	1.02	266.67	0.68	1.70
38	*Macrosolen parasiticus*	Shrub	1.33	6.00	0.68	133.33	0.34	1.02
39	*Maesa indica*	Tree	2.25	5.33	1.36	450.00	1.15	2.51
40	*Medinilla malabarica*	Shrub	1.75	5.33	0.91	233.33	0.59	1.50
41	*Meliosma pinnata*	Tree	2.33	5.33	1.70	583.33	1.49	3.19
42	*Microlepia strigose*	Fern	1.00	5.33	0.11	16.67	0.04	0.16
43	*Microtropis ramiflora*	Tree	2.23	5.33	1.48	483.33	1.23	2.71
44	*Osbeckia aspera*	Shrub	1.67	5.33	1.02	250.00	0.64	1.66
45	*Osbeckia reticulata*	Shrub	1.42	4.67	1.36	283.33	0.72	2.08
46	*Osmunda huegeliana*	Fern	1.00	4.67	0.11	16.67	0.04	0.16
47	*Pavetta breviflora*	Shrub	2.00	4.00	1.02	300.00	0.76	1.79
48	*Phymatosorus cuspidatus*	Fern	1.00	4.00	0.11	16.67	0.04	0.16
49	*Pogostemon benghalensis*	Shrub	1.78	3.33	1.02	266.67	0.68	1.70
50	*Psychotria nigra*	Shrub	2.10	3.33	1.14	350.00	0.89	2.03
51	*Psychotria nilgiriensis*	Shrub	1.69	2.67	3.97	983.33	2.51	6.48
52	*Pteridium revolutum*	Fern	1.00	2.00	0.11	16.67	0.04	0.16
53	*Pteris longipes*	Fern	1.00	2.00	0.11	16.67	0.04	0.16

Sl. No	Species Name	Habit	As	Fs	RFs	Ds	RDs	IVIs
54	*Rhodomyrtus tomentosa*	Tree	1.92	2.00	2.84	800.00	2.04	4.88
55	*Rubus glomeratus*	Climber	1.00	2.00	0.34	50.00	0.13	0.47
56	*Rubus niveus*	Climber	1.00	2.00	0.11	16.67	0.04	0.16
57	*Rubus ellipticus*	Climber	1.00	1.33	0.34	50.00	0.13	0.47
58	*Sarcococca coriacea*	Shrub	1.71	1.33	0.79	200.00	0.51	1.30
59	*Satyrium nepalense*	Herb	1.60	0.67	0.57	133.33	0.34	0.91
60	*Schefflera racemosa*	Tree	1.92	0.67	1.48	416.67	1.06	2.54
61	*Selaginella increscentifolia*	Fern	1.00	0.67	0.11	16.67	0.04	0.16
62	*Selliguea montana*	Fern	1.00	0.67	0.11	16.67	0.04	0.16
63	*Smilax zeylanica*	Herb	2.05	0.67	2.16	650.00	1.66	3.81
64	*Strobilanthes lawsoni*	Herb	3.43	0.67	5.22	2633.33	6.71	11.94
65	*Strobilanthes luridus*	Shrub	6.43	0.67	9.42	8900.00	22.69	32.11
66	*Strobilanthes neoasper*	Shrub	3.66	0.67	4.31	2316.67	5.91	10.22
67	*Strobilanthes tristis*	Shrub	2.13	0.67	2.61	816.67	2.08	4.69
68	*Symplocos obtusa*	Tree	1.95	0.67	2.27	650.00	1.66	3.93
69	*Symplocos pendula*	Herb	1.75	0.67	0.91	233.33	0.59	1.50
70	*Syzygium densiflorum*	Tree	2.72	0.67	2.04	816.67	2.08	4.13
71	*Syzygium lanceolatum*	Tree	1.33	0.67	1.02	200.00	0.51	1.53

Sl. No	Species Name	Habit	As	Fs	RFs	Ds	RDs	IVIs
72	*Tetrastigma leucostaphylum*	Herb	1.50	0.67	0.91	200.00	0.51	1.42
73	*Toddalia asiatica*	Climber	1.00	0.67	0.34	50.00	0.13	0.47
74	*Vaccinium leschenaultii*	Tree	1.56	0.67	2.04	466.67	1.19	3.23
75	*Vernonia anamallica*	Climber	1.00	0.67	0.45	66.67	0.17	0.62

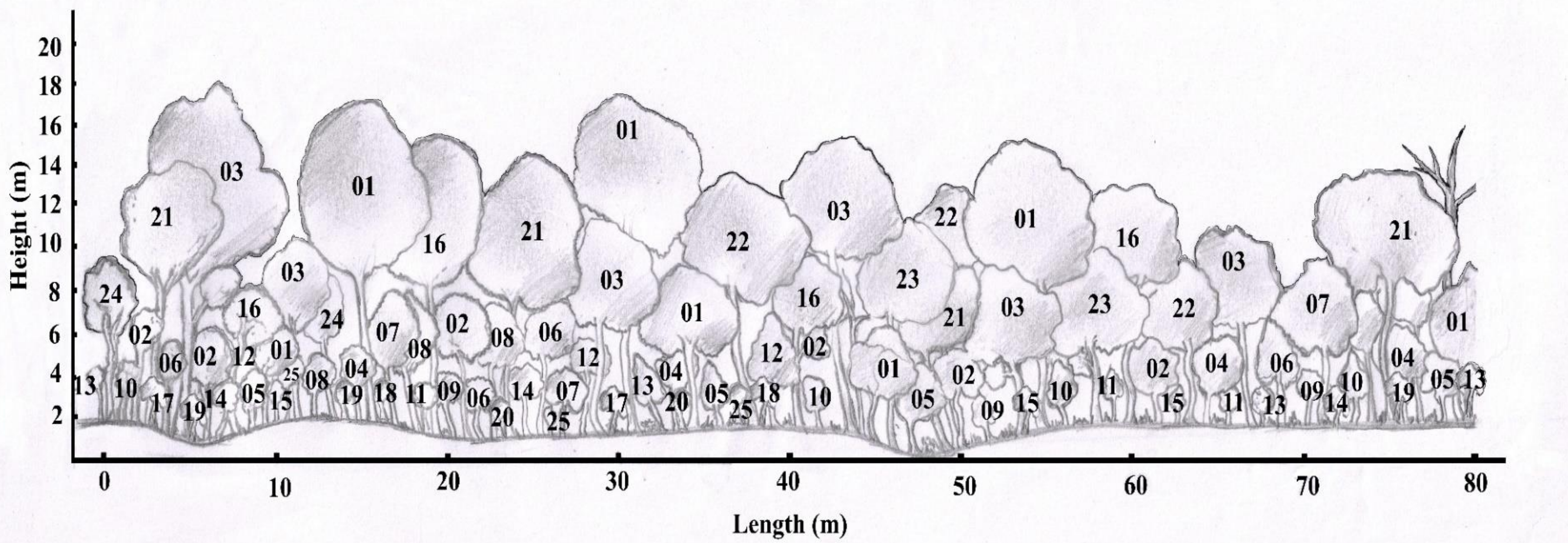

Fig. 13. Profile diagram of an 80 m x 10 m strip of shola forest at Mankulam Forest Division. 01, *Microtropis ramiflora* Wight, 02, *Vaccinium leschenaultii* var. leschenaultia., 03, *Actinodaphne bourdillonii* Gamble., 04, *Dodonaea viscosa* (L.) Jacq., 05, *Schefflera racemosa* (Wight) Harms., 06, *Syzygium lanceolatum* (Lam.) Wight & Arn., 07, *Syzygium densiflorum* Wall. ex Wight & Arn., 08, *Cinnamomum sulphuratum* Nees., 09, *Rhodomyrtus tomentosa* (Aiton) Hassk., 10, *Symplocos obtusa* Wall., 11, *Ixora notoniana* Wall. ex G.Don., 12, *Elaeocarpus recurvatus* Corner., 13, *Rhododendron arboreum* Sm., 14, *Litsea wightiana* (Nees) Hook. f., 15, *Maesa indica* (Roxb.) A. DC., 16, *Gordonia obtusa* Wall. ex Wight & Arn., 17, *Meliosma pinnata* (Roxb.) Maxim., 18, *Daphniphyllum neilgherrense* (Wight) K.Rosenthal., 19, *Mahonia leschenaultii* (Wall. ex Wight & Arn.) Takeda., 20, *Euonymus angulatus* Wight., 21, *Elaeocarpus munroii* Mast., 22, *Cinnamomum malabatrum* (Burm.f.) J.Presl., 23, *Glochidion bourdillonii* Gamble., 24, *Neolitsea scrobiculata* Gamble., 25, *Litsea floribunda* (Bl.) Gamble.

4.2.11 Profile Diagram

Profile diagram of representative 80 m × 10 m strips of the shola forest is shown in Fig. 13. A total Number of 86 individual tree species are identified from the 80 m × 10 m strip plot. In which Lauraceae is the dominant family in the profile diagram followed by Myrtaceae. From the total individual tree encountered from the profile diagram only 8.1% species exceeds 15 m height. So, it is evident from the profile diagram that trees are moreover less short boled and rarely exceed 15 m. The dominant species in the upper strata are *Microtropis ramiflora, Actinodaphnae bourdilloni, Gordonia obtusa, Eleocarpus munroii* and *Cinnamomum malabatrum*. The dominant ones in the lower storey comprised of *Schefflera racemosa, Mahonia leschenaultia, Dodonia viscosa, Symplocos obtusa, Litsea wightiana* and *Rhododendron arboreum*.

4.2.12 Family wise Importance value index of plant species (≥10 cm GBH)

Nine hundred and eighteen (GBH > 10 cm) individuals belonging to 33 different families was recorded with a density of 1836 individuals per hectare (Table. 13). Lauraceae had 332 individuals per hectare followed by Myrtaceae with 198 individuals per hectare. As a matter of fact, 18.19 per cent of the trees in the study area were from Lauraceae. Lauraceae was observed in 92 per cent of the quadrats, while Myrtaceae was present in 78 per cent of the quadrats and Celastraceae in 66 per cent of the quadrats. Fig. 14 and Table 13 depicts the Family wise Importance value index (FIVI) of plant species (≥10 cm GBH). The family level IVI value is highest for Lauraceae (47.32), followed by Myrtaceae (30.64) and Celastraceae (21.87). The lowest family IVI was for Icacinaceae (1.47).

Table. 13 Family wise Importance value index of plant species (≥10 cm GBH)

Sl. No	Family	F_F	RF_F	D_F	RD_F	BA_F	RBA_F	FIVI
1	Aquifoliaceae	22	2.30	34	1.85	0.19	1.88	6.03
2	Araliaceae	42	4.39	76	4.14	0.39	3.81	12.34
3	Asteraceae	12	1.26	18	0.98	0.15	1.45	3.69
4	Berberidaceae	36	3.77	52	2.83	0.18	1.80	8.40
5	Celastraceae	66	6.90	142	7.73	0.73	7.23	21.87
6	Clusiaceae	14	1.46	18	0.98	0.12	1.22	3.66
7	Daphniphyllacaeae	30	3.14	60	3.27	0.19	1.90	8.30
8	Elaeocarpaceae	48	5.02	86	4.68	0.52	5.08	14.78
9	Ericaceae	40	4.18	68	3.70	0.23	2.24	10.13
10	Flacourtiaceae	12	1.26	14	0.76	0.05	0.52	2.54
11	Icacinaceae	6	0.63	6	0.33	0.05	0.51	1.47
12	Lauraceae	92	9.62	334	18.19	1.98	19.50	47.32
13	Leguminosae	12	1.26	18	0.98	0.19	1.88	4.12
14	Myristicaceae	12	1.26	12	0.65	0.08	0.80	2.71
15	Myrsinaceae	32	3.35	54	2.94	0.36	3.55	9.84
16	Myrtaceae	78	8.16	198	10.78	1.19	11.70	30.64
17	Oleaceae	12	1.26	14	0.76	0.05	0.48	2.50

Sl. No	Family	F_F	RF_F	D_F	RD_F	BA_F	RBA_F	FIVI
18	Pentaphylacaceae	12	1.26	16	0.87	0.05	0.52	2.65
19	Phyllanthaceae	18	1.88	26	1.42	0.25	2.43	5.73
20	Pittosporaceae	12	1.26	16	0.87	0.08	0.76	2.88
21	Primulaceae	16	1.67	20	1.09	0.08	0.77	3.53
22	Rosaceae	12	1.26	12	0.65	0.06	0.62	2.52
23	Rubiaceae	42	4.39	72	3.92	0.23	2.30	10.62
24	Rutaceae	16	1.67	22	1.20	0.08	0.82	3.69
25	Sabiaceae	40	4.18	68	3.70	0.26	2.56	10.45
26	Sapindaceae	48	5.02	84	4.58	0.38	3.76	13.36
27	Staphyleaceae	12	1.26	16	0.87	0.13	1.33	3.45
28	Stemonuraceae	12	1.26	12	0.65	0.07	0.69	2.59
29	Symplocaceae	54	5.65	100	5.45	0.64	6.34	17.44
30	Theacaeae	32	3.35	54	2.94	0.30	2.99	9.28
31	Thymelaeaceae	16	1.67	20	1.09	0.10	0.95	3.71
32	Vacciniceae	34	3.56	64	3.49	0.66	6.50	13.55
33	Verbanaceae	14	1.46	30	1.63	0.11	1.10	4.20

(F_F= Frequency, RF_F= Relative Frequency, D_F=Density, RD_F=Relative Density, BA_F=n Basal Area, RBA_F= Relative Basal Area, FIVI= Family Important Value Index)

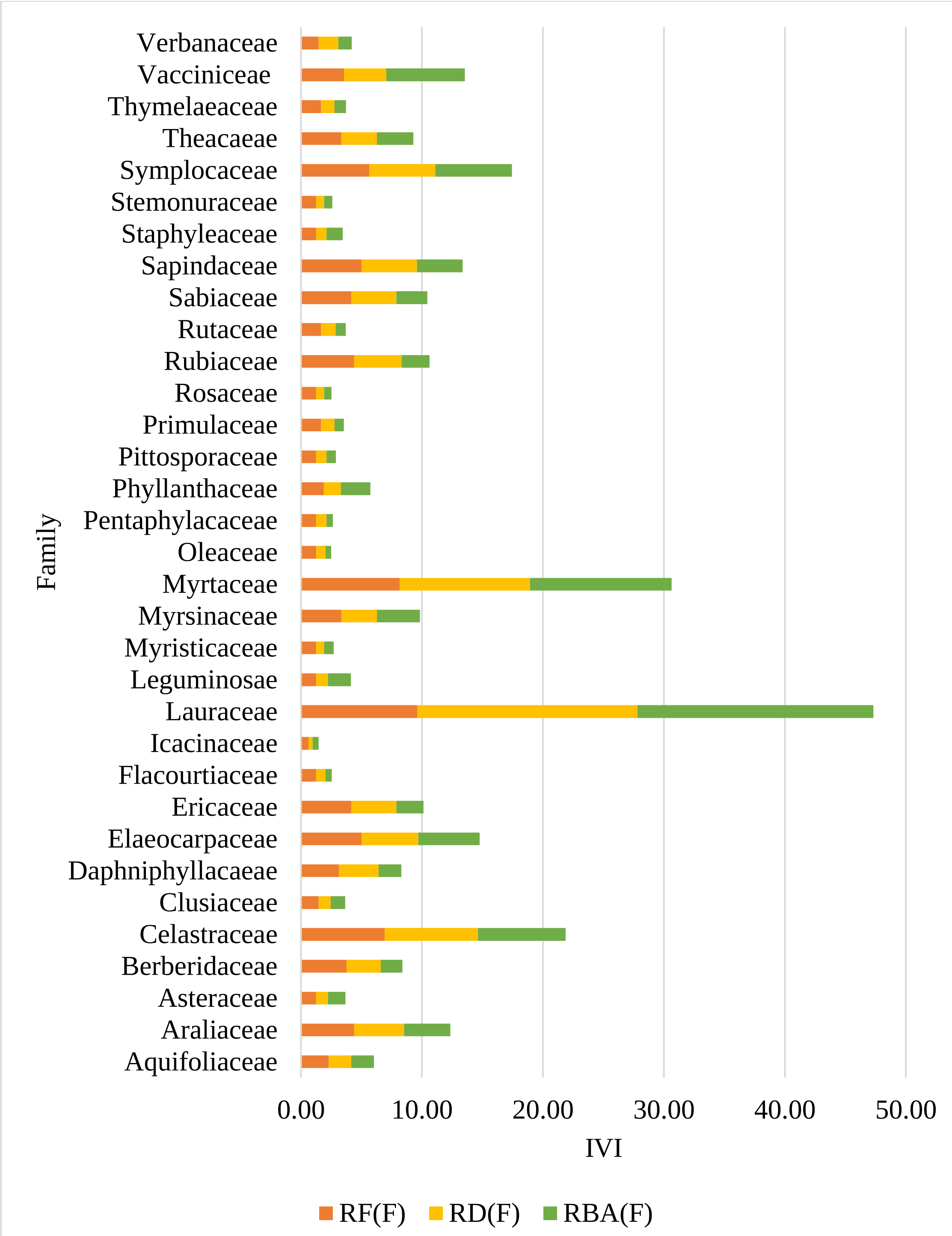

Fig 14. Family wise Importance value index of plant species (≥10 cm GBH)

4.3 DIVERSITY INDICES

The Simpson's index of the shola forest was 0.97 and the Berger- Parker Dominance Index was 0.05. The Shannon – Wiener index was 3.67 and Pielou's Equitability index was 0.93. The Margaleaf Richness index was 7.18 (Table 14).

Table 14. Floristic diversity indices of shola species (≥10 cm GBH) at MFD

Sl. No	Diversity indices	Value
1	Simpson Diversity Index	0.97
2	Shannon – Wiener Index	3.67
3	Berger-Parker Dominance Index	0.05
4	Margalef Richness Index	7.18
5	Pielou's Wiener Equitability Index	0.93

4.4 SOIL PHYSICO- CHEMICAL CHARACTERISTICS

The physico- chemical characteristics of soil were studied at a depth of 0 – 20 cm by evaluating the soil texture, bulk density (BD), electrical conductivity (EC), total Nitrogen (N), available Phosphorus (P), available Potassium (K), soil organic carbon (SOC) and soil pH.

4.4.1 Physical properties of the soil in shola forest of MFD

The physical properties of the shola forest soil were analyzed based on texture, electrical conductivity and bulk density.

4.4.1.1 Soil texture

The maximum sand content recorded was 75% and the minimum was 45%. The clay content of the soil varied from 35% to 20%. The silt content of shola forest soil varied from 22.5% to 2.5%. The mean percentage of sand was 60.95% followed by clay (24.35%) and silt (14.7%). The textural analysis revealed that the soil textural class belongs to Sandy Clay Loam based on the percentage contribution of sand silt and clay as per the USDA classification. (Fig. 15)

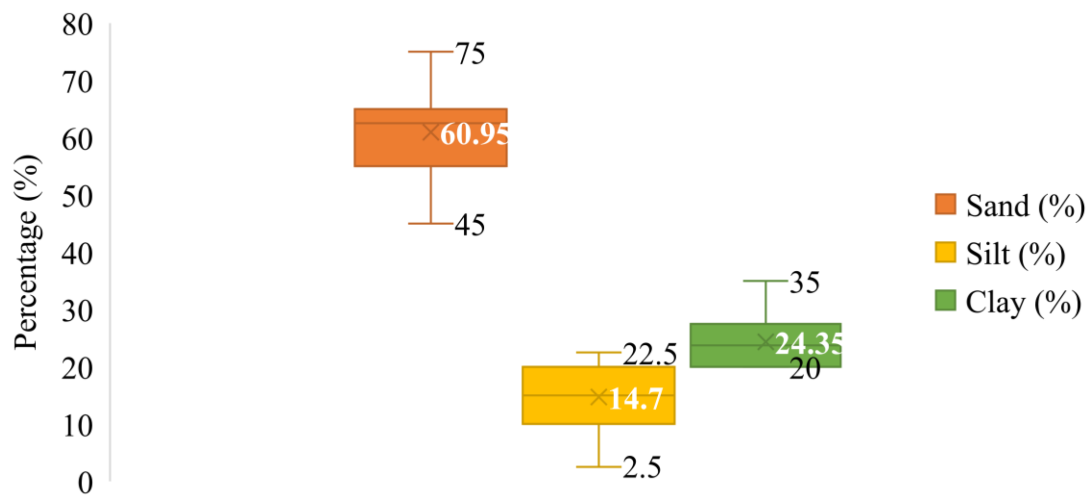

Fig. 15. Boxplot analysis for soil texture of soil at shola forest, MFD

4.4.1.2 Electrical conductivity

The Electrical Conductivity (EC) of the soil in the shola forest ecosystem varies from 0.29 dS/m to 0.94 dS/m with mean value 0.52 dS/m (Fig. 16).

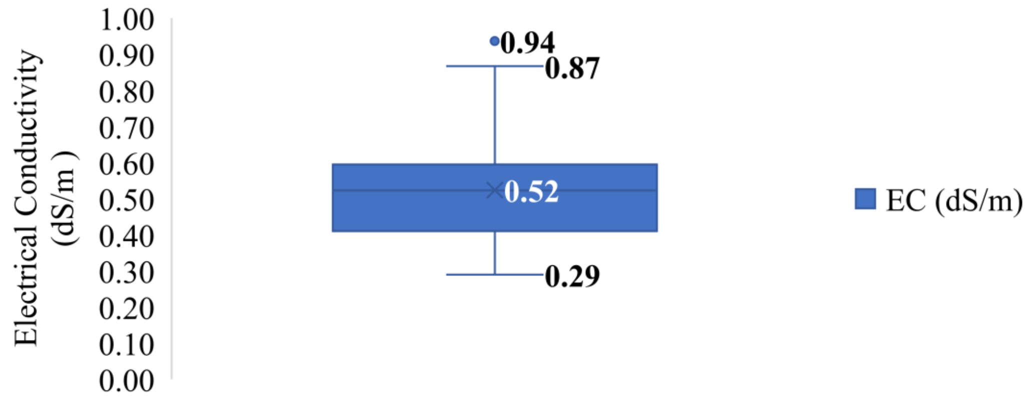

Fig. 16. Boxplot analysis for electrical Conductivity of shola forest soil, MFD

4.4.1.3 Bulk density

The Bulk Density (BD) of the soil in the shola forest ecosystem was low ranged from 0.42 g/ cm^3 to 1.29 g/ cm^3 with mean value 0.82 g/ cm^3 (Fig. 17).

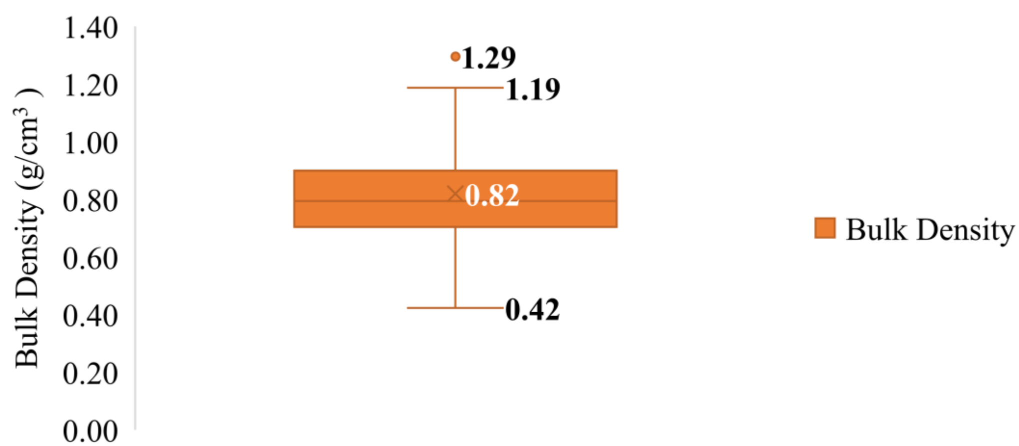

Fig. 17. Boxplot analysis for bulk density of shola forest soil, MFD

4.4.2 Chemical properties of the soil in shola forest of MFD

The chemical properties of the shola forest soil were analyzed based on pH, Soil Organic Carbon (SOC %), total Nitrogen (N), available Phosphorus (P), available Potassium (K).

4.4.2.1 Soil pH

Shola soil seem to be moderate to slightly acidic and pH values ranged between 4.67 to 5.84 (Fig. 18).

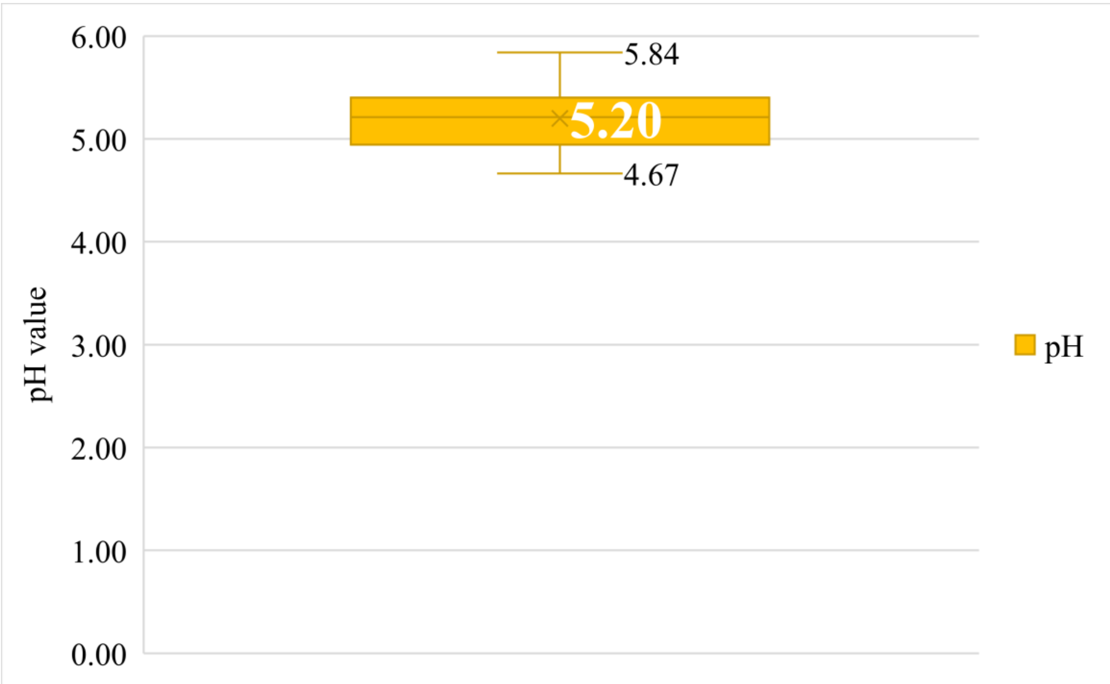

Fig. 18. Boxplot analysis for pH of shola forest soil

4.4.2.2 Soil Organic Carbon (SOC)

In the entire study area, the Soil Organic Carbon (SOC) content was high ranged between 5.18% to 9.71%, and the mean value of Soil Organic Carbon was 7.99% (Fig. 19).

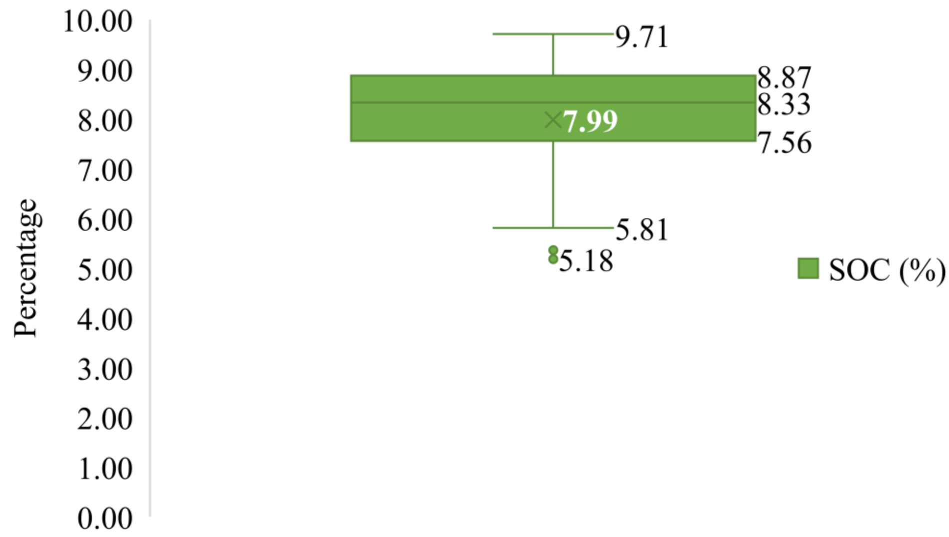

Fig. 19. Boxplot analysis for soil organic carbon (SOC) % of shola forest soil

4.4.2.3 Total Nitrogen

The Total Nitrogen content was high and varying from 1.01 % to 2.69 % and the mean percentage value of Total Nitrogen (N) was 1.85 % (Fig. 20)

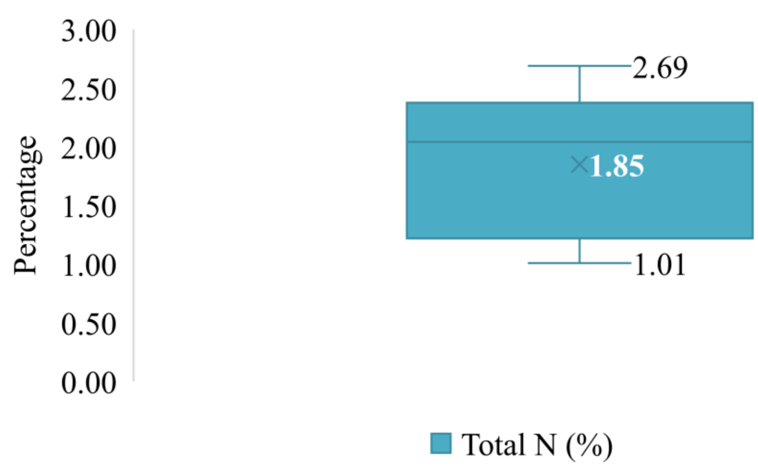

Fig. 20. Boxplot analysis for total nitrogen (N) in Shola forest soil

4.4.2.4 Avilable Phosphorus

The available Phosphorus (P) content was low varying from 32.65 Kg/ha to 98.39 Kg/ha and the mean value of available Phosphorus (P) was 71.58 Kg/ha (Fig. 21)

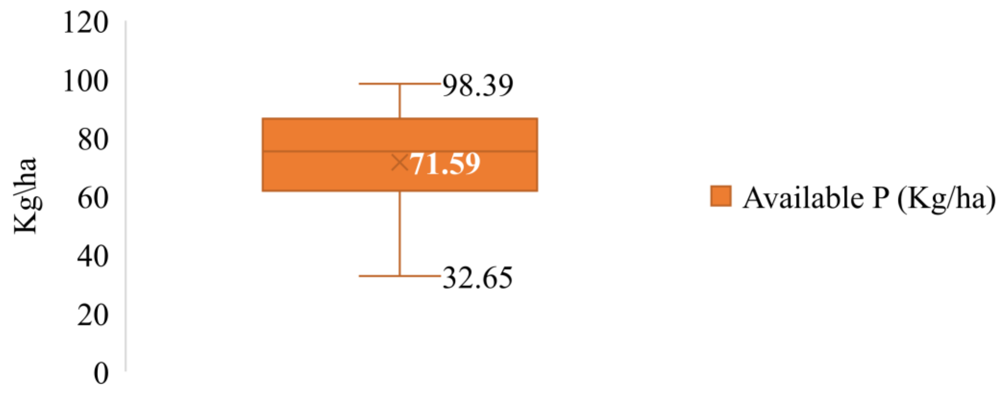

Fig. 21. Boxplot analysis for available phosphorus (P) in shola forest soil

4.4.2.4 Available Potassium

The available Potassium (K) content was high in the shola soils varies from 262.02 Kg/ha to 766.30 Kg/ha and the mean value of available Potassium (K) 562.42 Kg/ha (Fig.. 22).

Fig.. 22. Boxplot analysis for available potassium (K) in shola forest soil

4.5 DETRENDED CORRESPONDENCE ANALYSIS (DCA)

The major gradients in the species composition were studied through detrended correspondence analysis (DCA). For ecological interpretation of the ordination axes, ecological factors were also incorporated in the DCA graph.

From the study, it was observed that in sites 1, 2, 7, 10, 12, 20, 24, 35, 37 and 47 the predominant species found were *Nothapodytes nimmoniana, Maesa indica, Litsea wightiana, Elaeocarpus recurvatus, Rhododendron arboretum, Cinnamomum malabatrum, Elaeocarpus munroii, Neolitsea scrobiculata, Ligustrum perrottetii, Cinnamomum sulphuratum and Gordonia obtusa* Whereas in sites 5, 8, 11, 14, 15, 16, 18, 21, 22, 25, 31, 33 and 45 species like *Pittosporum neelgherrense, Turpinia cochinchinensis, Neolitsea cassia, Ilex gardneriana, Ardisia rhomboidea, Euonymus angulatus, Garcinia cowa, Meliosma pinnata, Symplocos cochinchinensis* was found to be dominant. In sites 6, 8, 9, 17, 19, 26, 28, 36, 43 and 50 have species like *Actinodaphne bourdillonii, Syzygium lanceolatum, Dodonaea viscosa, Gomphandra coriacea, Ixora notoniana* was found to be dominant. In sites like 3, 4, 30, 32, 34, 38, 39, 40, 42, 44, 46, 48 and 49 the predominant species were *Acronychia pedunculata, Schefflera racemosa, Rhodomyrtus tomentosa, Litsea floribunda, Meliosma pinnata, Syzygium densiflorum* (Fig. 23).

The species like *Nothapodytes nimmoniana, Maesa indica, Litsea wightiana, Elaeocarpus recurvatus, Cinnamomum malabatrum, Elaeocarpus munroii, Neolitsea scrobiculata, Ligustrum perrottetii, Cinnamomum sulphuratum, Ilex wightiana and Gordonia obtuse* factors contributing to their growth are pH, soil organic carbon (SOC) and available potassium (AK). Species like *Actinodaphne bourdillonii, Syzygium lanceolatum, Dodonaea viscosa, Gomphandra coriacea, Ixora notoniana* the factor contributing to their abundance is electrical conductivity (EC). Species like *Glochidion bourdillonii, Casearia thwaitesii, Meliosma pinnata, Rhodomyrtus tomentosa, Schefflera racemose, Euonymus angulatus* and bulk density was found to be the significant factor contributing for the presence of these species (Fig. 24).

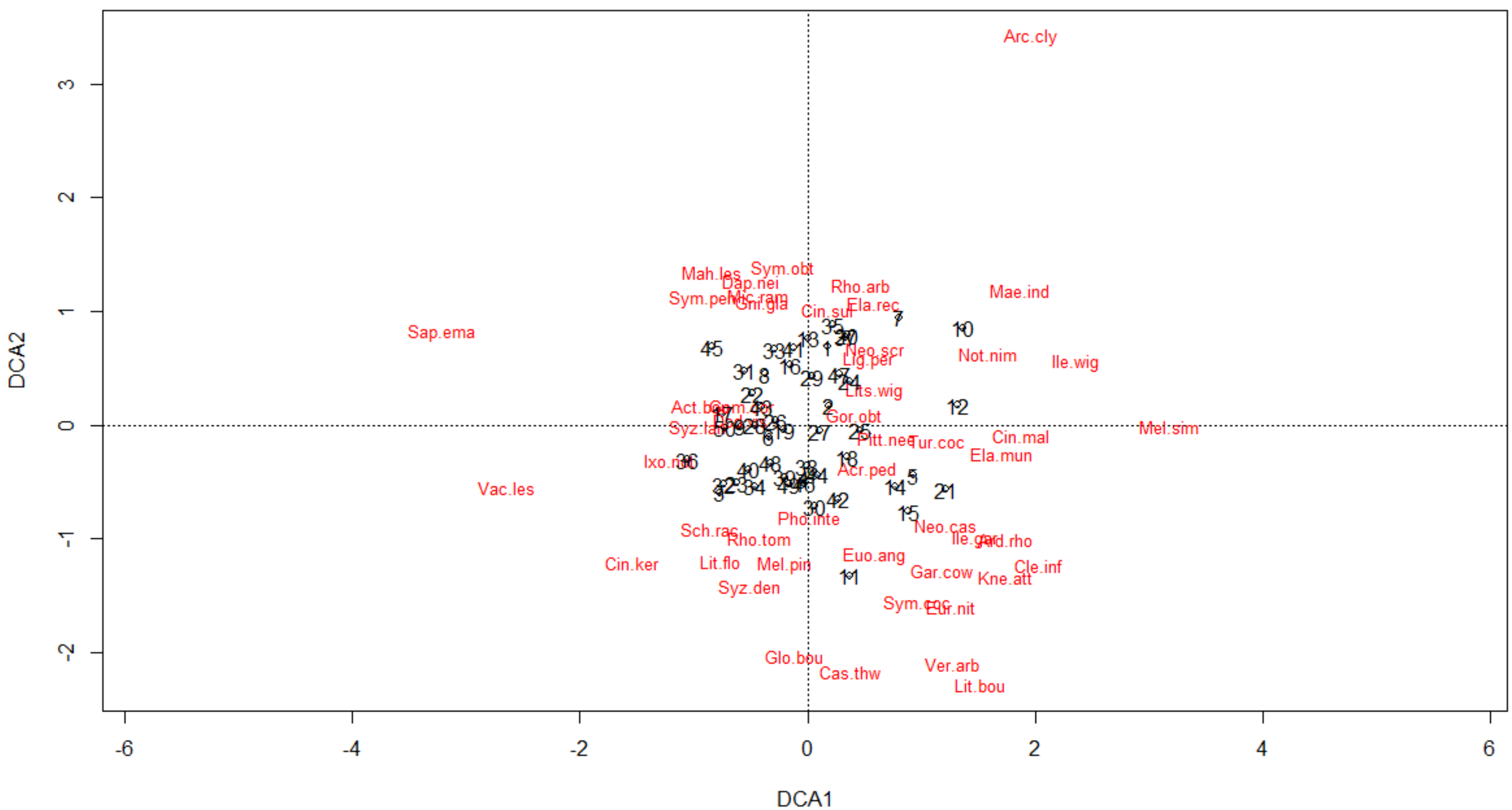

Fig. 23. Detrended correspondence analysis (DCA) for tree species and site at shola forest of MFD

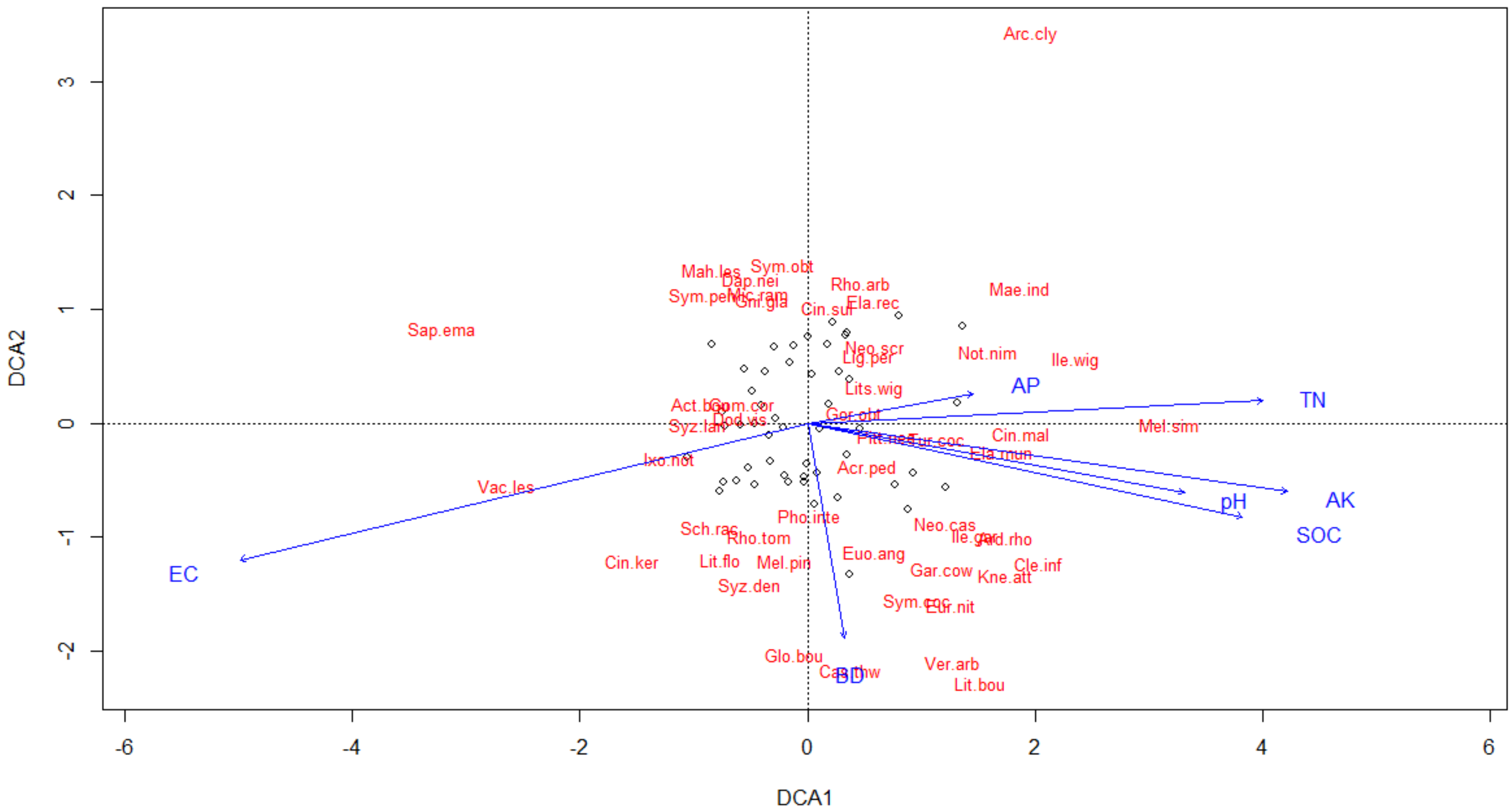

Fig. 24. Detrended correspondence analysis (DCA) for tree species and ecological factors of shola forest of MFD

Discussion

5. DISCUSSION

The present study was carried out during 2018 – 2020 for understanding the floristic and edaphic attributes of a shola forest (Southern montane wet temperate forest: 11A/C1) located in the Mankulam forest division in Kerala. The results of the findings are discussed below.

5.1 FLORISTIC ATTRIBUTES OF SHOLA FOREST

This study of the Mankulam shola could record 50 tree species, 20 shrubs, 12 herbs, 8 climbers, and 16 ferns (Fig 1) from a 0.5 ha area. At the family level, Lauraceae was the dominant family in the upper storey, followed by Myrtaceae and Symplocaceae (Fig. 2) which is not a surprising observation in a shola forest. Earlier workers had observed that Lauraceae was generally dominant in the upper storey (Mohandass and Davidar, 2009), except in shola forests of Eravikulam (Menon, 2001), who reported the domination of Myrtaceae in this area. Swarupanandan *et al*. (2001) too has found the domination of Myrtaceae, however, they tend to be patchier in their dominance, being displaced from the Pambadam shola national park by Rubiaceae and Euphorbiaceae in some regions. Euphorbiaceae (Sudhakara, 2001) was the second dominant group in some Anamalai sholas but poorly encountered in the Upper Nilgiris. Also, the study conducted by Vidyasagaran *et al*. (2004) reported a similar observation that the Lauraceae family showed the maximum representation in the Bramagiri sholas of Wayanad district. The high-altitude evergreen forests as well as montane sholas are known to be dominated by Lauraceae members and the present study also gives strong evidence for this kind of floristic formation.

At MFD shola, the understory was dominated by plant species from Rubiaceae and Acanthaceae (Table 2 and Table 3). Rubiaceae has historically been influential in the shola understory (Ashton 1988; Nair *et al.,* 2001). In the present study too, *Strobilanthus* sp. was found to be the dominant genus in the underground storey which goes well with an earlier observation by Jose *et al*. (1994) from sholas of Eravikulam

National Park. Fyson (1920) too had described 19 *Strobilanthus* sp. from Nilgiri sholas and reported that some are limited to the edges of shola forests.

Table 15. Comparison of the number of tree species encountered in the and evergreen forest ecosystem

Study site	**Reference**	**No. of tree species encountered**	**Area (ha)**	**Forest type**
Eravikulam National Park	Jose *et al*. (1994)	53	0.5	Shola
Mannavan	Chandrashekara *et al*. (2006)	51	0.25	Shola
Ammagel reserve forest	Mohandass *et al.* (2016)	62	1	Shola
Brahmagiri and Pakshipathalam of Thirunelly, Wayanad district	Vidyasagaran *et al*. (2004)	44	0.5	Shola
Kalakad–Mundanthurai Tiger Reserve	Ganesh *et al*. (1996)	85	0.6	Evergreen
Silent Valley National Park	Singh *et al*. (1981)	84	0.4	Evergreen
MFD		**50**	**0.5**	**Shola**

Table 15. documents the number of tree species encountered in the shola and evergreen forest ecosystem found in different tropical forest locations. The number of tree species is comparatively higher in the evergreen forest compared to the shola forests of Mankulam forest division and elsewhere. But between the shola forests, the

numbers are in the reported range. The typical larger diversity of tree species in an evergreen forest can be attributed to the complex multi-storied nature whereas in a typical shola forest tree stratification is less compared to an evergreen forest. This can be due to the presence of a harsh environment and the factors are frost, highly prevailing wind and slope effect as in the true temperate region (Didham and Ewers, 2014)

5.2 FLORISTIC STRUCTURE

Tree girth class distribution trend may be viewed as a predictor of stand quality. The frequency distribution of the GBH classes is given in Table 8 and Fig. 7. Number of individuals was decreasing with increasing GBH classes. Tree distribution by GBH class intervals shows that 38.13% of individuals were in the GBH class of 10 cm to 20 cm, followed by 23.85% in the GBH class of 20 cm to 30 cm, by 11.55% in the GBH class of 30 cm to 40 cm, by 8.39% in the GBH class of 40 cm to 50 cm, by 6.32% in the GBH class of 50 cm to 60 cm and by 4.58% in the GBH class of 60 cm to 70 cm. Only 7.19% of the individuals were in the GBH class of >70 cm. Thus, it shows an inverse 'J' shaped curve, indicating the higher number of trees in the lower diameter class. This trend indicates a continuous regeneration with younger recruits (Khamyong *et al*., 2003). This regular pattern is similar to those reported from the other sholas namely sholas of Eravikulam National park (Jose *et al*., 1994), Eastern Ghats (Sahu *et al*., 2012) and Andaman island (Rasingam and Parthasarathy, 2009).

Trees in shola forest of MFD was rarely exceeded 15 m. The frequency distribution of the height classes is given in Table 10 and Fig. 9. Tree distribution by height class intervals shows that 49.89% of individuals were in the height class of 1.5 m to 4 m, followed by 35.29% of individuals in the height class of 4.1 m to 6.5 m, by 11.55% of individuals in the height class of 6.6 m to 9 m. Only 3.27% of the individuals were in the GBH class of >9.1 m. Thus, it shows an inverse ‘J’ shaped distribution. Tree height limitations on shola forest can attributed to the strong winds that prevailed in the high plateau and low temperature (Davidar *et al*., 2007). In MFD shola ecosystem also, which is also located at a height of >1800 m, winds are strong also very frequent with an average annual temperature of 16°C.

From the profile diagram (Fig. 13), it is evident that trees are more or less short boled and rarely exceed 15m. Jose *et al*. (1994) has also expressed the view that the shola forest of Eravikulam has trees with short boled and rarely exceeds 12 m. The stunted nature of the shola forest and confinement of the shola forest into island condition is due to many reasons such as the shola stand properties which differ with temperature and humidity (Ashton, 2003). The lapse in temperature and cloud condensation also varies according to the size of the mountain scale and mountain distances from the coast (Grubb and Whitmore, 1966, Jarvis and Mulligan, 2011). Whereas more humid air condenses at lower altitudes, while drier air masses need colder temperatures to form clouds at higher elevations. Temperature lapse rates on smaller mountains could be steeper due to the "Massenerhebung" impact that encourages plants to expand their upslope ranges to larger mountains (Scatena *et al*., 2010, Jarvis and Mulligan, 2011). Confining the shola forest into an island which restricts the survival and growth of the tropical tree species above 2000m altitude due to the soil temperature and low average air (Ohsawa 1991; Korner and Paulsen, 2004, Caner *et al*., 2007).

Table 16. Comparison of trees per hectare in the shola and evergreen forest ecosystem

Study site	**Reference**	**Tree density** (ha^{-1})	**Forest type**
Eravikulam National Park	Jose *et al*. (1994)	1884	Shola
Brahmagiri and Pakshipathalam, Thirunelly, Wayanad district	Vidyasagaran *et al*. (2004)	2533	Shola
Silent Valley National Park	Basha (1987)	1082	Evergreen

Western Ghats (20 localities)	Achar *et al*. (2000)	616	Evergreen
Someshvar reserve forest, south Canara district	Srinivas and Parthasarathy, 2000	1067	Evergreen
Devimane, Katlekan, Kodkani and Malemane hills of karanataka state	Pomeroy *et al*., 2003	412	Evergreen
Uppangala forest, Kadamakal reserve forest, Kodagu district	Pascal and Pelissier, 1996	635	Evergreen
Eastern Ghats of northern Andhra Pradesh	Reddy *et al*., 2011	654	Evergreen
Saptasajya hill range of Eastern Ghats	Sahu *et al*., 2019	390	Evergreen
MFD		**1836**	**Shola**

Table 16. outlines the findings by different researchers on tree density per hectare in shola and evergreen forest ecosystem in different locations. The tree density value obtained in the current study is almost similar to the other studies conducted in the shola forests. The number of tree density per hectare is much higher compared to other reports from the evergreen forest. This can be due to the greater number of individuals in the lower girth classes in shola forests which could be the reason for a higher density, compared to the evergreen forests (Fig. 9). Memiaghe *et al*. (2016), suggested that high levels of diversity within small diameter groups can provide high levels of resistance to the disturbances in the forests, which may be true in the case of shola forests.

Table 17. Comparison of basal area ($m^2\ ha^{-1}$) in shola and evergreen forest ecosystem

Study site	**Reference**	**Basal area ($m^2\ ha^{-1}$)**	**Forest type**
Brahmagiri and Pakshipathalam of Thirunelly, Wayanad district	Vidyasagaran *et al*. (2004)	73.55	Shola
Eravikulam National Park	Jose *et al*. (1994)	48	Shola
Ammagel reserve forest	Mohandass *et al*. (2016)	53.20	Shola
Vaguvarrai, Idukki district	Sreejith *et al*. (2015)	35.28	Shola
Karian shola in Parambikulam wildlife sanctuary	Suraj *et al*. (2016)	50.50	Shola
Kalakad– Mundanthurai Tiger Reserve	Ganesh *et al*. (1996)	40.03	Evergreen
Silent Valley National Park	Singh *et al*. (1981)	102.7	Evergreen
Nelliampathy, Palakkad district	Chandrashekara and Ramakrishnan, 1994	66.9	Evergreen
Eastern Ghats of northern Andhra Pradesh	Reddy *et al*., 2011	39.97	Evergreen
Saptasajya hill range of Eastern Ghats	Sahu *et al*., 2019	22.21	Evergreen
MFD		**22.46**	**Shola**

Table 17. depicts the basal area (m^2 ha^{-1}) of shola and evergreen forest ecosystems. The basal area of trees in MFD is quite lower compared to the other shola forest ecosystems in Kerala. Compared to evergreen forests, the basal area is less at the MFD shola forest. This can be due to the presence of a higher percentage of individuals in the lower diameter classes (Fig. 9.) which is typically combined with stunted nature. From personal observation, it was found that the MFD shola patch was compactly packed, having a close canopy and higher stocking with lower basal area. Lower basal area of trees in the MFD in comparison with other shola forests could be due to a combination of the above-mentioned factors.

5.3 DIVERSITY INDICES

Forests also vary significantly with respect to species diversity in the tropical region. The diversity indices describe the general characteristics of communities that enable researchers to compare various regions (Morris *et al*., 2014). Table 19 gives the Simpson index, Shannon diversity index and Berger-Parker Dominance Index of different shola and evergreen forest ecosystems. The Simpson diversity index of MFD shola is slightly higher than the others (Table 18). The general range of Simpson's index of diversity in the shola forests is 0.94 and in an evergreen forest, it ranged from 0.85 to 0.95 (Table 18). The Simpson index from the shola forest of MFD indicates that the probability of two individuals randomly selected from the sample site belongs to different species (Magguran, 2004)

Earlier studies report a Shannon index range of around 2.5 to 5.45 for the Western Ghats shola forests (Table 18) which is comparable with the current study also (Table 14). The evergreen forests of Western Ghats are showing a wide range of Shannon-Weiner index values (Table 18). The comparatively medium value of the Shannon-Weiner index value (H') of the current study can be attributed to the fact that H' is more sensitive to the effect on the abundance of the species (Abhilash and Menon, 2009).

The Berger-Parker Dominance Index observed for MFD shola forest was 0.05 (Table 14) and a similar observation was reported by Jose *et al.* (1994) from Eravikulam National Park which is situated near to the present field of study. Since the value of Berger-Parker Dominance Index gives an idea of that the species are evenly distributed in the shola forest of MFD (Magguran, 2004).

Table 18. Comparison of Simpson index, Shannon diversity index and Berger-Parker Dominance Index in shola and evergreen forest ecosystems

Study site	**Reference**	**Simpson index**	**Shannon diversity index**	**Berger-Parker Dominance Index**	**Forest type**
Eravikulam National Park	Jose *et al*., 1994	0.94	4.86	0.05	Shola
Brahmagiri and Pakshipathalam of Thirunelly, Wayanad district	Vidyasagaran *et al*., 2004	0.94	5.45	0.06	Shola
Mannavan shola reserve and Eravikulam shola forests	Swarupanandan *et al.*, 2001	_	2.5 - 3.38	_	Shola
Eravikulam National Park	Nair and Menon (2001)	_	3.24	_	Shola
Pampadum Shola National Park	Sudhakara (2001)	_	4.53	_	Shola
Amaggal reserve forest, Nilgiris	Mohandass *et al*. (2016)	0.95	3.24	_	Evergreen

Kodayar, Kanyakumari	Sundarapandian and Swamy, 1999	0.85	2.64	_	Evergreen
Uppangala forest, Kodagu district	Pascal and Pelissier, 1996	0.92	4.56	_	Evergreen
Eastern Ghats of northern Andhra Pradesh	Reddy *et al*., 2011	0.96	5.18	_	Evergreen
Saptasajya hill range of Eastern Ghats	Sahu *et al*., 2019	0.62	1.29	_	Evergreen
MFD		**0.97**	**3.67**	**0.05**	**Shola**

Evenness is the degree to which individuals are divided among species with low values suggesting that one or more species dominate, and high values mean that fairly equal numbers of individuals belong to each species (Morris *et al.*, 2014). In the present study, the Pielou Evenness index was 0.93 (Table 14) which indicates an even distribution of individuals among species in the study area. This index value is close to other such reports from tropical evergreen forests (Table 19) which indicates more consistency in species distribution in shoals and evergreen forests (Devi *et al*., 2018).

The Margalef index measures the abundance of the species and is especially sensitive to sample size because it attempts to account for the impact of sampling (Magguran, 2004). In the present study, the Margaleaf diversity index was found to be 7.28 (Table 14). The diversity of species is higher in sholas of Mankulam in comparison with the evergreen forest. This can be due to the effect of higher altitude, as the Mankulam sholas are over 1800 meters above sea level (Reddy *et al*., 2011). Several authors have used different altitudinal thresholds to describe the lower boundary of shola in the Western Ghats ranging from 1500 m by Ranganathan (1938); Meher-Homji (1967), 1700 m in Bunyan *et al*. (2012) and 1800 m in Nair and Khanduri (2001).

Table 19. Comparison of Pielou evenness index and Margalef richness index in evergreen forest ecosystem with MFD shola

Study site	**Reference**	**Pielou Evenness Index**	**Margalef Richness Index**	**Forest type**
Agasthyamalai	Varghese and Balasubramanyan (1999)	0.89	7.07	Evergreen
Kodayar, Kanyakumari	Sundarapandian and Swamy, 1999	1.69	_	Evergreen
Saptasajya hill range of Eastern Ghats	Sahu *et al*., 2019	0.68	_	Evergreen
MFD		**0.93**	**7.28**	**Shola**

5.4 SOIL PHYSICO- CHEMICAL CHARACTERISTICS

5.4.1 Physical properties of the soil in shola forest of MFD

The present study revealed the presence of a higher mean percentage of sand (60.95%) followed by clay (24.35%) and silt (14.7%). The general textural character of this shola forest was sandy clay loam as per USDA guidelines (Fig. 15). The shola soils in the MFD were having a dark reddish-brown color with a loose, friable, crumb structure and with abundant roots. Table 20 shows the comparison of soil texture in the shola forest ecosystem and evergreen forest ecosystem, it can be seen that sand content is dominating in both reports of shola and evergreen forest. The higher sand content in the soil can be attributed to the climatic conditions of typical sholas forests where primary weathering occurs due to annual/perennial streams and similar water bodies. The further weathering to finer silt and clay from sand and gravel are restricted by lower temperature (Vishnu *et al*., 2017).

The soil at MFD showed a lower bulk density compared to that of an evergreen forest ecosystem (Table 20) with an average bulk density of 0.82 g cm^{-3} (Fig. 17). The lower bulk density can be attributed to higher organic content and higher porosity (Nandakumar, 2004). At MFD shola, soil organic carbon was higher (Fig. 19) and the sand content too was higher (Fig. 15) which could be the primary reason for the lower BD values.

The EC of the soil at MFD was average (0.52 dS/m) which was similar to that of an evergreen forest ecosystem (Table 20). As per the USDA criteria, an EC value less than 1dS/m is considered as non-saline. The lower EC values of the soil at MFD or any other shola can be due to the high rate of absorption of minerals from the soil by plants and due to leaching which occurs due to the constant water movement in sholas. Shola soils play an important role in maintaining and conserving the water and annual/perennial streams (Thomas and Shankar, 2001). Other than rainfall the constant movement of water through the sholas increases the leaching of macro-micro nutrients from the soil (Smith, 1990). Resulting in reduced soil salinity (Provin and Pitt, 2001).

Table 20. Comparison of physical properties of the soil in shola and evergreen forest ecosystems

Study site	**Reference**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**BD (g cm^{-3})**	**EC (dS/m)**	**Forest type**
Kerala part of Western Ghats	Sandeep and Sujatha (2014)	92	4	4	_	_	Shola
Chembra Peak area, Meppadi Forest Range	Thomas and Sankar (2002)	76 to 78	9	13 to 17	_	_	Shola
Deomali Reserve Forest in Arunachal Pradesh	Barbhuiya *et al*., 2004	58.30	12	29.70	_	_	Evergreen (undisturbed site)
Kerala part of Western Ghats	Sandeep and Sujatha (2014)	81	11	8	_	_	Evergreen
Shendurney Wildlife Sanctuary	Asok and Sobha (2014)	_	_	_	1.05	_	Evergreen
Brahmagiri and Pakshipathalam of Thirunelly, Wayanad district	Vidyasagaran *et al*. (2004)	_	_	_	_	0.50 to 0.62	Shola

Saptasajya hill range of Eastern Ghats	Sahu *et al.*, 2019	-	-	-	-	0.16	Evergreen
Indira Gandhi Wildlife Sanctuary, Pollachi	Saravanakumar and Kaviyarasan (2010)	_	_	_	_	0.65	Evergreen
MFD		**60.95**	**14.70**	**24.35**	**0.82**	**0.52**	**Shola**

5.4.2 Chemical properties of the soil in shola forest of MFD

The Mankulam shola soil was moderately acidic to slightly acidic (Fig. 18). A similar observation was made from the other shola forests. Comparing an evergreen forest ecosystem and this shola forest ecosystem, it can be seen that the pH values are similar (Table 21). Mankulam forest division receives an average rainfall of 2,500 mm to 3,000 mm and they are restricted by temperature with mean annual temperature ranges from 5°C to 30°C (GOK, 2012). The combined effect of low temperature and high rainfall in shola forests and grasslands restricts the biochemical decomposition of organic residues in these soils and thus contributes to the maintenance of a high organic carbon content, which in turn is responsible for the high cation exchange capacity and the base saturation of these soils (Balagopalan and Jose, 1993).

Soil organic carbon content at MFD shola was high (Fig. 19). A similar observation was made by Jose *et al.* (1994) from Eravikulam National Park. Comparing reports from the evergreen forest ecosystem and this shola forest ecosystem (Table. 21) it can be seen that soil organic carbon is higher in the shola forest of MFD. This can be due to the accumulation of organic matter from above and belowground plant litter and maximum soil microbial and root activities. Forest litter quality, soil-plant biomass (above and belowground), climatic factors and soil microbial activities are a major factor for the accumulation of soil organic carbon (Ravindranath and Ostwald, 2008). Also, annual or more regular decay and death of the fine roots of forest soils provide essential organic matter and carbon sequestration contributions, adding to soil productivity cycles and supplying large carbon storage facilities (Boyle, 2005). Higher accumulation of soil organic carbon in the MFD could be due to a combination of the above-mentioned factors.

The higher total nitrogen (Fig. 26) in the shola is perhaps due to the accumulation of soil organic carbon which is a favorable factor for the production of total soil nitrogen (Tesfaye *et al*., 2016). There are already reports that the soil organic carbon and total nitrogen follows a similar pattern where they show a significant correlation between them (Peng *et al*., 2013). The shola forest of MFD was seen in the core area of forest and sharing boundary with the Eravikulam National Park. Hence the disturbance level is less. Thus, the higher soil organic carbon and total nitrogen levels could also be due to the low level of disturbance on the soil (Tolessa and Senbeta, 2018). Nitrogen is used by the vegetations less effectively and more recycled in the soil by litterfall. Higher accumulation of total nitrogen in the MFD shola soils could be due to a combination of the above-mentioned factors.

The available phosphorous in the present study was found to be lower than other shola forests, but higher than values from the evergreen forest (Table. 21). Phosphorous is mainly dependent on the plant litter since phosphorous is deficient in the forest soil. Climatic stress such as low temperature and high nitrogen input decreases the ability of the soil in efficient phosphorous recycling (Jonard *et al*., 2015). In the Mankulam forest division, the mean annual temperature ranges from 5°C to 30°C (GOK, 2012) and the accumulation of total nitrogen content in the shola soils of MFD is higher. Temperature is one of the major factors controlling the soil nitrogen and species composition which regulates the soil available phosphorous content (Zheng *et al*., 2017). These factors can be attributed to the lower soil phosphorous levels in MFD.

The available potassium value ranges observed at MFD shola are similar to the shola forest of Eravikulam national park (Jose *et al*., 1994). This can be due to the high accumulation of organic carbon (Fig. 19) and soil organic matter which might have contributed to high humus content in the soil. The presence of the humus and soil organic matter is a key feature of tropical montane cloud forests (Hamilton *et al*., 1995).

Table 21. Comparison of chemical properties of the soil in shola and evergreen forest ecosystem

Study site	**Reference**	**pH**	**SOC**	**TN**	**AP**	**AK**	**Forest type**
Eravikulam National Park	Jose *et al*. (1994)	_	22.48*	1.21*	0.02*	0.017*	Shola
Brahmagiri and Pakshipathalam, Thirunelly	Vidyasagaran *et al*. (2004)	4.9 to 5.7	3.24* to 3.48*	0.11* to 0.12*	_	0.02*	Shola
Brahmagiri, Thirunelly	Thomas and Shankar (2001)	5.60	2.80*	_	_	0.18*	Shola
Nilgiri Hills	Venkatachalam *et al*. (2007)	5.44	_	_	_	138.49**	Shola
Ecuador	Wilcke *et al*. (2008)	4.60	39*	2.10*	0.87*	0.35*	Shola (1960 m)
Ecuador	Wilcke *et al*. (2008)	3.90	48.5*	1.80*	0.57*	0.11*	Shola (2090 m)
Ecuador	Wilcke *et al*. (2008)	4.40	33.6*	1.20*	0.34*	0.11*	Shola (2450 m)
Deomali Reserve Forest	Barbhuiya *et al.* (2004)	4.29 to 6.59	1.33* to 1.84*	0.45* to 0.80*	_	_	Evergreen

Kerala	Vishnu *et al*. (2017)	5.1	_	_	_	_	Evergreen
Sholayar	Rajesh *et al*. (1996)		3.35* to 3.93*	_	_	_	Evergreen
Makutta range, Kodagu district	Devagiri *et al*. (2016)	_	1.44* to 2.23*	_	47** to 62**	241** to 289**	Evergreen
Saptasajya hill range of Eastern Ghats	Sahu *et al*., 2019	5.66	0.61*	0.26*	0.11*	_	Evergreen
MFD		**4.67 to 5.84**	**7.99***	**1.85***	**71.58****	**562.42****	**Shola**

(* = %, ** = kg ha^{-1}, SOC= Soil Organic Carbon, TN=Total Nitrogen, AK= Available Potassium, AP= Available Phosphorous)

5.5 DETRENDED CORRESPONDENCE ANALYSIS (DCA)

The variables in detrended correspondence analysis are defined by arrows that point to the full change in length and in proportion to the change rate (ter Braak 1987). Each arrow defines an axis to be used to project the species points. In general, for each environmental consideration these estimation points predict the optimal species distribution. From the study, in sites 1, 2, 7, 10, 12, 20, 24, 35, 37 and 47 the predominant species found were *Nothapodytes nimmoniana, Maesa indica, Litsea wightiana, Elaeocarpus recurvatus, Rhododendron arboretum, Cinnamomum malabatrum,Elaeocarpus munroii, Neolitsea scrobiculata, Ligustrum perrottetii, Cinnamomum sulphuratum and Gordonia obtusa* Whereas in sites 5, 8, 11, 14, 15, 16, 18, 21, 22, 25, 26, 31, 33 and 45 species like *Pittosporum neelgherrense, Turpinia cochinchinensis, Neolitsea cassia, Ilex gardneriana, Ardisia rhomboidea, Euonymus angulatus, Garcinia cowa, Meliosma pinnata, Symplocos cochinchinensis* was dominant. In sites 6, 8, 9, 17, 19, 26, 28, 36, 43 and 50 have species like

Actinodaphne bourdillonii, Syzygium lanceolatum, Dodonaea viscosa, Gomphandra coriacea, Ixora notoniana was found to be dominant. In sites like 3, 4, 30, 32, 34, 38, 39, 40, 42, 44, 46, 48 and 49 the predominant species were *Acronychia pedunculata, Schefflera racemosa, Rhodomyrtus tomentosa, Litsea floribunda, Meliosma pinnata, Syzygium densiflorum* (Fig. 23).

The findings of the ordination clearly indicate vegetational and environmental variability and the interaction between variation in vegetation and the environment factors (Jin-Tun and Oxley, 1994). The species like *Nothapodytes nimmoniana, Maesa indica, Litsea wightiana, Elaeocarpus recurvatus, Cinnamomum malabatrum, Elaeocarpus munroii, Neolitsea scrobiculata, Ligustrum perrottetii, Cinnamomum sulphuratum, Ilex wightiana and Gordonia obtuse* factors contributing to their growth in the current study was pH, soil organic carbon (SOC) and available potassium (AK). Species like *Actinodaphne bourdillonii, Syzygium lanceolatum, Dodonaea viscosa, Gomphandra coriacea, Ixora notoniana* the factor contributing to their abundance is electrical conductivity (EC). Species like *Glochidion bourdillonii, Casearia thwaitesii, Meliosma pinnata, Rhodomyrtus tomentosa, Schefflera racemose and Euonymus angulatus* in which bulk density was contributing for the presence of these species (Fig. 24).

To sum up, the shola forests of Mankulam forest division exhibits high floristic diversity and comparatively better soil physico-chemical properties vis-à-vis tropical evergreen forests. Typical shola plant families (trees under Lauraceae, Myrtaceae, Celastraceae and Symplocaceae) and (understorey vegetation represented by Acanthaceae, Myrtaceae, Lauraceae and Rubiaceae) could be recorded in the study area which re-emphasizes the ecological uniqueness of this area. The presence of a greater number of species in the lower girth classes is indicative of its regeneration potential. Higher soil values (soil organic carbon, total nitrogen) indicate the soil fertility status of this ecosystem. All these attributes make this shola at MFD a special candidate for special protection and conservation activities.

Future line of study

During the present study the presence of introduced species (*Eucalyptus* sps) observed within and periphery of the shola forest could affect their structural and functional dynamics and can have significant impact on the natural regeneration of the typical shola species in the long run. Additionally, a more detailed study covering tree crown diameter, canopy gap, edge effect of the shola forest, micro-climate, characteristics of the soil, profile and fauna needs to be undertaken to create valuable benchmark data on this “habitat specialists”. Gathering information on soil Ca and Mg along with probing. The soil microbial and macro-faunal activities will help to develop a comprehensive understanding of their functional ecology of this shola forest. Studies on the ecotones to compare and contrast the neighboring ecosystems will also be yielding valuable data that will protect this unique ecosystem.

Summary

6. SUMMARY

The study titled "Floristic and edaphic attributes of a shola forest ecosystem in Mankulam Forest Division, Kerala" was conducted to understand the floristic composition, diversity and vegetation structure of a shola forest ecosystem in Mankulam forest division, Kerala and to also investigate the physico-chemical properties of soil that supports this unique forest ecosystem. The results obtained from this study are summarized below.

1. At the shola forest of Mankulam forest division, this study could record 106 plant species. This list includes 50 species of trees, 20 shrubs, 12 herbs, 8 climbers and 16 fern species.
2. *Microtropis ramiflora*, *Vaccinium leschenaultia*, *Actinodaphne bourdillonii*, *Daphniphyllum neilgherrense*, *Schefflera racemosa*, *Syzygium lanceolatum*, *Syzygium densiflorum*, *Cinnamomum sulphuratum*, *Rhodomyrtus tomentosa and Symplocos obtusa* are the dominant tree species in Mankulam shola.
3. *Microtropis ramiflora*, *Dodonaea viscosa*, *Rhodomyrtus tomentosa*, *Ixora notoniana*, *Schefflera racemosa* and *Syzygium lanceolatum* had the highest percentage frequency.
4. *Actinodaphne bourdillonii*, *Cinnamomum malabatrum*, *Cinnamomum sulphuratum*, *Elaeocarpus munroii*, *Gordonia obtusa*, *Litsea bourdillonii* and *Microtropis ramiflora* and *Syzygium densiflorum* was represented in the higher diameter classes (> 100 cm).
5. *Actinodaphne bourdillonii*, *Cinnamomum malabatrum*, *Elaeocarpus munroii*, *Gordonia obtusa*, *Microtropis ramiflora* and *Syzygium densiflorum* showed representation in the height classes (> 11.6 m.).
6. The density was 918 individuals with a basal area of 22.46 $m^2 ha^{-1}$.

7. The diameter frequency as well as height frequency distribution of shola forest displayed an inverse J shaped curve which reflects the existence of a fairly good population of young recruits.
8. Lauraceae, Myrtaceae and Celastraceae are the tree dominant families.
9. The diversity indices of the shola forest ecosystem are Simpson's index (0.97), Berger- Parker Dominance Index (0.05), Shannon – Wiener index (3.67), Pielou's Equitability index (0.93) and the Margaleaf Richness index (7.18).
10. *Strobilanthes luridus, Ageratina adenophora, Strobilanthes lawsone* and *Strobilanthes neoasper* are the dominant understory plant species.
11. The density of the understory plant species was 2353 individuals belonging to 75 different species.
12. The profile diagram showed that the trees are more or less short boled and rarely exceed 15m.
13. The dominant species in the upper strata of profile diagram was *Microtropis ramiflora*, *Actinodaphnae bourdilloni*, *Gordonia obtusa*, *Eleocarpus munroii* and *Cinnamomum malabatrum*.
14. The dominant ones in the lower storey of profile diagram comprised of *Schefflera racemosa, Mahonia leschenaultia, Dodonia viscosa, Symplocos obtusa, Litsea wightiana* and *Rhododendron arboreum*.
15. Soil was sandy clay loam with sand (60.95%), followed by clay (24.35%) and silt (14.7%).
16. The electrical conductivity (EC) of the soil varies from 0.29 dS/m to 0.94 dS/m with mean value 0.52 dS/m.
17. The bulk density (BD) of the soil ranged from 0.42 g cm^{-3} to 1.29 g $cm^{-3}$with mean value 0.82 g cm^{-3}.
18. Shola soil seem to be moderate to slightly acidic and pH values ranged between 4.67 to 5.84.
19. The soil organic carbon (SOC) content ranged between 5.18% to 9.71%, and the mean value of soil organic carbon was 7.99%.

20. The total nitrogen content varies from 1.01 % to 2.69 % and the mean percentage value of total nitrogen (N) was 1.85 %.
21. The available phosphorus (P) content varies from 32.65 Kg/ha to 98.39 kg ha^{-1} and the mean value of available phosphorus (P) was 71.58 kg ha^{-1}.
22. The available potassium (K) varies from 262.02 kg ha^{-1} to 766.30 kg ha^{-1} and the mean value of available potassium (K) 562.42 kg ha^{-1}.

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FLORISTIC AND EDAPHIC ATTRIBUTES OF A SHOLA FOREST ECOSYSTEM IN MANKULAM FOREST DIVISION, KERALA

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ABSTRACT OF THE THESIS

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ABSTRACT

A study was undertaken in the shola forest ecosystem at Anakulam range of Mankulam forest division, Idukki, Kerala with a principal objective to understand the floristic composition, diversity and vegetation structure and also to investigate the physico-chemical properties of soil that supports this unique forest ecosystem. On this context the hypothesis examined was whether the shola forest exhibits high floristic diversity, structure and soil properties comparable to tropical evergreen forests. A total of 106 plant species was recorded from 0.5 ha. It included 50 species of trees, 20 shrubs, 12 herbs, 8 climbers and 16 fern species. The diversity indices of the shola forest ecosystem were Simpson's index (0.97), Berger- Parker Dominance Index (0.05), Shannon – Wiener index (3.67), Pielou's Equitability index (0.93) and Margaleaf Richness index (7.18) which are on par with similar published reports from the shola forests and tropical evergreen forests. A total number of 918 individuals were recorded from 0.5ha with a basal area of 22.46 m^2 ha^{-1}. *Microtropis ramiflora, Vaccinium leschenaultia, Actinodaphne bourdillonii, Daphniphyllum neilgherrense, Schefflera racemosa, Syzygium lanceolatum, Syzygium densiflorum, Cinnamomum sulphuratum, Rhodomyrtus tomentosa and Symplocos obtuse* are the dominant tree species in Mankulam shola. Lauraceae, Myrtaceae and Celastraceae are the tree dominant families. The diameter frequency as well as height frequency distribution of shola forest showed the "inverse J" shaped curve which reflects the existence of new recruits. The total number of plant species in the understory was 2353 belonging to 75 different species. The dominant understory plant species was *Strobilanthes luridus, Ageratina adenophora*, *Strobilanthes lawsone* and *Strobilanthes neoasper*. Profile diagram revealed that the trees are short boled and rarely exceed 15m. Soil was sandy clay loam (60.95%) followed by clay (24.35%) and silt (14.7%). Electrical conductivity was 0.52 dS/m, while bulk density was 0.82 g cm^{-3}. Shola soil was moderate to slightly acidic (4.67 to 5.84), while SOC content was 7.99%. Total nitrogen content was 1.85

% and available phosphorus was 71.58 kg ha^{-1}. The available potassium (K) was 562.42 kg ha^{-1} which are comparable to the published reports from the shola forests and tropical evergreen forests.