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# FLORISTIC COMPOSITION AND STRUCTURAL ANALYSIS OF FLORA IN NILGIRIS BIOSPHERE RESERVE, WESTERN GHATS OF SOUTHERN INDIA

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The field survey was conducted from April 2021–December 2021in Mettupalyam forest range of Coimbatore forest division which is an integral part of Nilgiris Biosphere Reserve. A systematic random sampling method with 60 sample plots of 20 × 20 m and 8 transect line survey at 0.2% sampling intensity were laid out in the study area which recorded 54 trees, 25 shrubs, 22 herbs and 22 grasses. The result revealed that the maximum dominance was observed in *Atlantia monophylla* (32.20), *Lantana camara* (43.02), *Abutilon indicum* (54.87) and *Oplismenus burmanii* (19.34%) and minimum in *Glycosmis pentaphylla* (12.32), *Euphorbia heterophylla* (2.18), *Mimosa pudica* (2.82) and *Melinis repens* (0.18%) in tree, shrubs, herbs and grass layer, respectively. Furthermore, the highest Shannon D index (H = 3.08) observed in tree layer, followed by grass layer (H = 2.76), herb layer (H = 2.28) and shrub later (H = 2.25) along with Simpson index also higher in grass layer (1-D = 0.92), tree layer (1-D = 0.91), herb layer (1-D = 0.86) and shrub layer (1-D = 0.84), respectively. This study involving the cataloguing of flora in Mettupalayam Reserve Forest is the pioneer work which provided scientific and baseline information for conservation of flora in the forested area.

Keywords: Catalogue, phytosociology attributes, reserve forest, conservation

## INTRODUCTION

The Niligiri Biosphere Reserve is located in south west India and north of the Palghat (10° 45' N latitude and 76° 10'–77° 10' E longitude), spreading over an area of 5600 km$^2$. The Reserve has diverse climate due to its varied reliefs and topography. Geological evidences suggest that the underlying rocks are Archaean which were about two billion years old. The mean annual rainfall varies from 600 mm in the eastern side to 2000 mm in the western side. The dry season is from January to April. Corresponding to the gradient in rainfall, the vegetation varies from southern tropical dry thorn forest in the east to moist deciduous forest in the west with dry deciduous forest in between the two forest types (Champion & Seth 1968). The Niligiri Biosphere Reserve is one of the most studied landscapes with regards to biodiversity in India. About 20% of all angiosperm species, 15% of butterflies and 23% of all vertebrates, excluding marine species in India were found in the Niligiri Biosphere Reserve. It is also a significant region for its endemic species. Out of the 3000 known angiosperm species, 82 (2.7%) are exclusive to this landscape (Daniels 1993). India's Nilgiri Biosphere Reserve, which is one among the 25 global hotspots of biodiversity with diverse endemic fauna and flora, is facing severe man-made ecological disturbances (Desai & Baskaran 1996, Silori & Mishra 1995 (2001).

According to the Forest Survey of India Report 2021, the total forest cover of the country is 713,789 km$^2$ which is 21.71% of India's total

geographical area. Tropical forest covers only 8% of the land area and yet supports a high level of biological variety with nearly half of all known species and a huge number of undiscovered species. Tropical forests are the most diverse terrestrial ecosystems, supporting a wide range of living forms and contributing significantly to world biodiversity (Dirzo & Raven 2003, Houghton 2005, Wilson 1988). The tropical forests which are ecologically highly imperative areas; nonetheless are under threat from population growth, urbanisation, deforestation, agriculture, degradation, loss of habitat, legal and illicit logging, mining, fire and climate change (May & Stumpf 2000, Singh et al. 2006, Goparaju & Jha 2010). Plant diversity encompasses the heterogeneity and wide variation of plant forms (Mudgal 1997, Shameem et al. 2010, Chowdhury et al. 2018). The vegetation patterns fluctuate from season to season in a cyclic fashion over the years in a successional manner. The fluctuations showed each species population is responding to prevailing temperature, humidity and sunlight as in tune by the vegetation (Heady 1958). The pattern of species distribution in a community is altered by the development and deterioration of plant species, topographic features and climatic differences (Watt et al. 2007, Karaköse 2019, Karaköse & Salih 2021). The necessity of measuring species richness is crucial for ensuring biodiversity protection (Rahman et al. 2011). In addition, floristic assessment of the forest is indispensable to detect the risk of extinction, arrival of invasive species and changes in plant diversity over time. Relatively wide range of studies were carried out to determine the forest floristic composition and forest structure in Western Ghats. An extensive assessment of the distribution of vascular plants in Western Ghats were conducted in Mudanthurai Tiger Reserve, Agasthyamalai Biosphere Reserve (Ganesh et al. 1996, Rao & Raghavendra 2012). The Mettupalayam Reserve Forest of Western Ghats holds significant population of fauna owing to its diverse distribution of flora but there is no scientific and systematic study on documentation of floristic composition in Mettupalayam Reserve Forest of Nilgiris Biosphere Reserve. In this context, there is an urgent requirement to generate the latest data on its floristic composition in the reserve forest. The objective of the present study focuses on determining the floristic structure and composition of the area. It is expected that the research findings will provide scientific baseline information for conservation of flora and fauna in the forest reserve.

## MATERIALS AND METHODS

### Study area

The field survey was conducted from April 2021 to December 2021 in the Mettupalayam Forest range of Coimbatore Forest Division (10° 37'–11° 31' N and 76° 39'–77° 5' E). Greater part of the division is situated southwardly extending in the Western Ghats with the North-western parts forming the lower ranges of the Nilgiris. Systematic random sampling method was conducted in the area using transect lines and sample plots in 6 areas of Mettupalayam range namely Jaccanari, Sundapatti, Nellimalai, Hulikal, Kandiyur and Kallar while their forest types were classified based on Champion and Seth (1968).

### Assessment of phytosociological characters

A transect line with 2 km length was marked in the study area for flora exploration and documentation. The size and number of sample plots were determined using the species effort curve technique (Misra 1968, Daniels 1996). Based on species effort curve, sample plots or quadrats with the size of 20 × 20 m for trees, 10 × 10 m for shrubs, 5 × 5 m for herbs and 1 × 1 m for grasses were placed and systematically surveyed using sampling intensity at 0.2%. Sample plots were laid opposite to each other direction and the distance between the sample plots were fixed as 200 m and 50 m from the transect line. A total of 80 sample plots and 8 transect lines were laid out in the study area. In each plot, the diameter at breast height and height of trees with a diameter at breast height of more or equal to 10 cm were recorded and location points were recorded using global positioning system. Based on the geo-referencing points, each the transect line and sample plots were marked on the google earth map (Figure 1). All flora in the plots were identified and recorded by local and scientific names. The grass samples were collected and identified by using hand book on some south Indian grasses (Achariyar & Mudaliyar 1921) and google lens application.

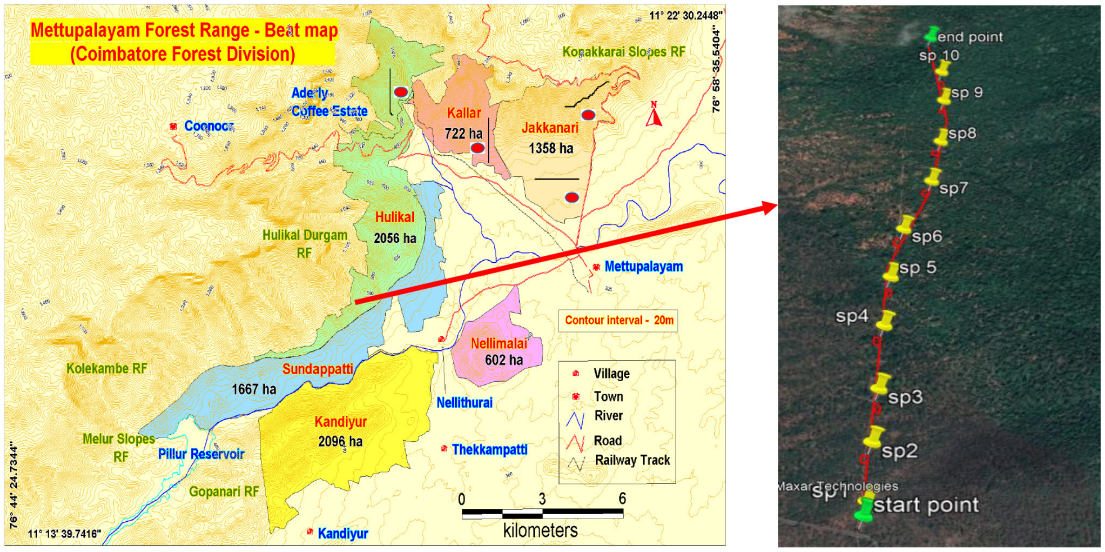


**Figure 1** Map view of transect lines and sample plot locations of Mettupalyam Reserve Forest using Google Map Earth

## Data analysis

### *Phytosociological characters*

The important phytosociological characters such as density, frequency and abundance, relative density, relative frequency, relative dominance and important value index of plant species were determined as recommended by Curtis and McIntosh (1951). The quantitative characters within the study area were assessed by using the following formula:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrants}}{\text{Total number of quadrats studied}}$$

$$\text{Frequency (\%)} = \frac{\text{Number of quadrants in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

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

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

$$\text{Relative frequency (\%)} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

$$\text{Relative dominance (\%)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

$$\text{IVI} = \text{RD (\%)} + \text{RF (\%)} + \text{Rd (\%)}$$

*Species diversity indices*

The following diversity indices were calculated by using PAST software (Hammer et al. 2001).

$$\text{Simpson index, } D = \frac{\sum ni(ni-1)}{N(n-1)}$$

where D = Simpson index of dominance, ni = the total number of trees of each individual species, N = the total number of trees of all species. As the value of D increases, diversity decreases and Simpson's index was therefore usually expressed as 1 – D or 1/ D (Simpson 1949).

$$\text{Shannon-Weiner index, } H' = -\sum pi \ln pi$$

where H' = Shannon index of diversity, pi = the proportion of important value of the $i^{th}$ species, pi = ni / N, ni = the important value index of $it^{h}$ species and N = the important value index of all the species), ln = natural logarithm on proportion of each species (Shannon & Weiner 1963).

$$\text{Pielou's evenness index, } J = H/\ln(S)$$

where H = Shannon-Weiner index, S = individuals of all the species, ln = natural logarithm on individuals of all the species (Pielou 1975).

$$\text{Margalef's index, } Dmg = (S-1)/\ln(N)$$

where S = total number of species, N = total number of individuals, ln = natural logarithm on total number of individuals (Margalef 1968).

Chao1 estimator,
where Q2 = number of species occurring in two samples, F1 = the number of singleton species, F2 = the number of doubleton species (Chao & Glibert 1980).

## RESULTS AND DISCUSSION

### Density, frequency, abundance and dominance (important value index) of flora

### Tree layer

A total of 54 species were recorded which belongs to 25 families, the highest number of species was registered in Fabaceae family (Figure 2a). On the species level *Atalantia monophylla* (9.19) was the most dominant species whereas the lowest density was recorded in *Ailanthus triphysa* and *Vitex altissima* (0.02) (Figure 3a). With respect to frequency, *Atlantia monophylla* showed maximum value at 92.59%, followed by *Sapindus emarginatus* and *Ziziphus glabrata* with the value of 75.93% and minimum values were observed in ten species such as *Albizia lebbeck, Ailanthus triphysa, Butea monosperma, Cassia spectabilis, Dalbergia latifolia, Diospyros montana, Glycosmis pentaphylla, Mallotus philippensis, Terminalia chebula* and *Vitex altissima* with the frequency of 1.85% respectively (Figure 3b). *Bambusa bambos* had highest abundance at 12.50 followed by *Atlantia monophylla* at 9.92 and lowest value was recorded in *Acacia planifrons* at 0.66 (Figure 3c). *Atalantia monophylla* showed highest important value index (32.20) followed by *Chloroxylon swietenia* (14.38), *Sapindus emarginatus* (12.32) while the lowest was observed in *Glycosmis pentaphylla* (1.19) (Table 1). The results revealed that *Atlantia monophylla* had maximum dominance in Mettupalayam Reserve Forest. This is because it grows well on all type of soils and seeds dispersed by ants and birds for longer distance which enhanced the local colonisation process and plant diversity of the area (Figure 3a). The high frequency and abundance of this species were most likely due to the presence of seeds, that were easily distributed as well as their ability to regenerate quickly (Figure 3b). This study was in accordance with the findings of Onyekwelu et al. (2008), L*ü* et al. (2010), Zhang et al. (2012), Mandal & Joshi (2014), Sathya (2017), Abdullahi & Abba (2021) and Oluwaseyi et al. (2021) who reported the important value index in *Khaya ivorensis* as 14.32, *Barringtonia macrostachya* as 54.88, *Castanopsis carlesii* var. *spinulosa* as 9.31, *Anogeissus latifolia* as 37.90, *Diospyros melanoxylon* as 36.04, *Protium serratum* as 34.69, *Azadirachta indica* as 37.10 and *Mangifera indica* as 22.93. However, some values were found to be lower than the findings of Shahid & Joshi (2016) in *Shorea robusta* at 187, Gebrewahid & Abrehe (2019) in *Acacia abyssinica* as 40.85, Okechalu et al. (2021) in *Daniellia oliveri* as 81.90, Sahu et al. (2019) in *Mangifera indica* as 112.76 which compared the ecological significance of species and indicated the extent of dominance of a species in the structural system of vegetation stand.

## Shrub layer

A sum of 25 shrubs were recorded in the shrub layer which belongs to 17 families and the higher number of species was observed in Euphorbiaceae family (Figure 2b). The maximum density (27.17) was recorded for *Lantana camara* followed by *Solanum violaceum* (14.09), *Chromolaena odorata* (13.37) (Figure 3a). The lowest value was registered in *Calotropis procera* (0.07). *Jasminum angustifolium* and *Lantana camara* had highest frequency percentage of 94.44 followed by *Solanum violaceum* at 79.63% and *Carmona retusa* showed lowest frequency percentage of 1.85 (Figure 3b). Abundance of *Lantana camara* exhibited maximum value of 28.76 followed by *Chromolaena odorata* (19.00), *Solanum violaceum* (17.70) compared to *Euphorbia heterophylla* L. (1.00) (Figure 3c) which led to increase in the important value index of *Lantana camara, Solanum violaceum* and *Chromolaena odorata* as 43.02, 26.72 and 25.03 respectively (Table 2). *Lantana camara* showed higher dominance in shrub layer (Figure 3a) which might be due to biological attributes such as fitness homeostasis, phenotypic plasticity, dispersal benefits from destructive foraging activities, widespread geographic range, vegetative reproduction, fire tolerance, better competitive ability than native flora and allelopathy. These are some of the biological attributes that contributed to Lantana's success as an invader species and abundant wind dispersed seeds which provided a greater reproductive capacity (Karaköse et al. 2018). *Lantana camara* invasions in natural communities were frequently linked to a reduction in species diversity as well as changes in ecosystem structure and function. Similar dominance of *Lantana camara* was also reported in moist deciduous forest of Odisha by Reddy & Pattanaik (2009), Khanduri et al. (2017) and Tiwari & Ravikumar (2018) respectively.

## Herb layer

Twenty-two herb species were documented in the herb layer which belongs to 16 families and Euphorbiaceae had highest number of species (Figure 2c). The highest herb density had been

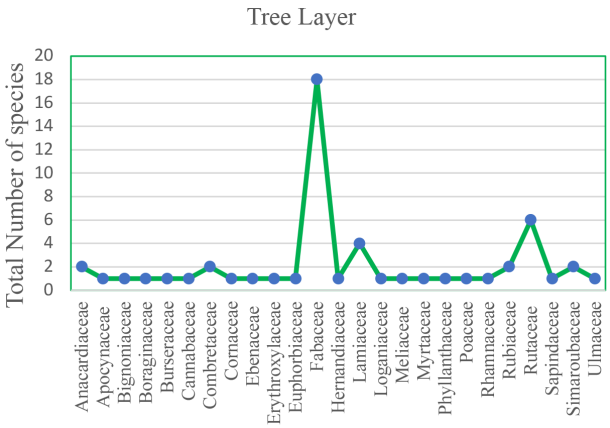


**Figure 2a** Distribution of family in Tree Layer

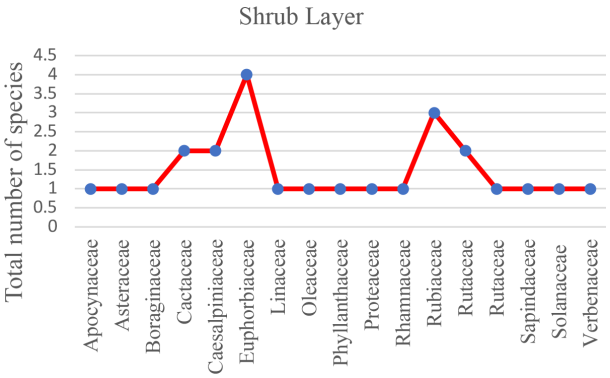


**Figure 2b** Distribution of family in Shrub Layer

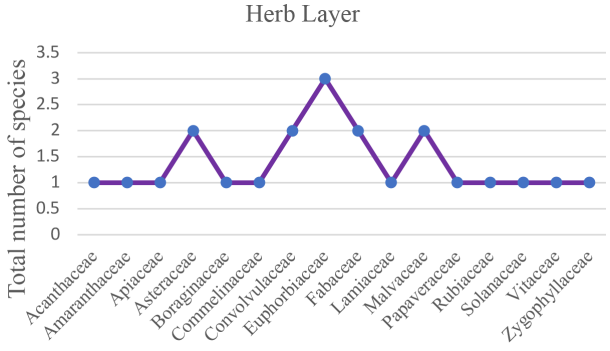


**Figure 2c** Distribution of family in Herb Layer

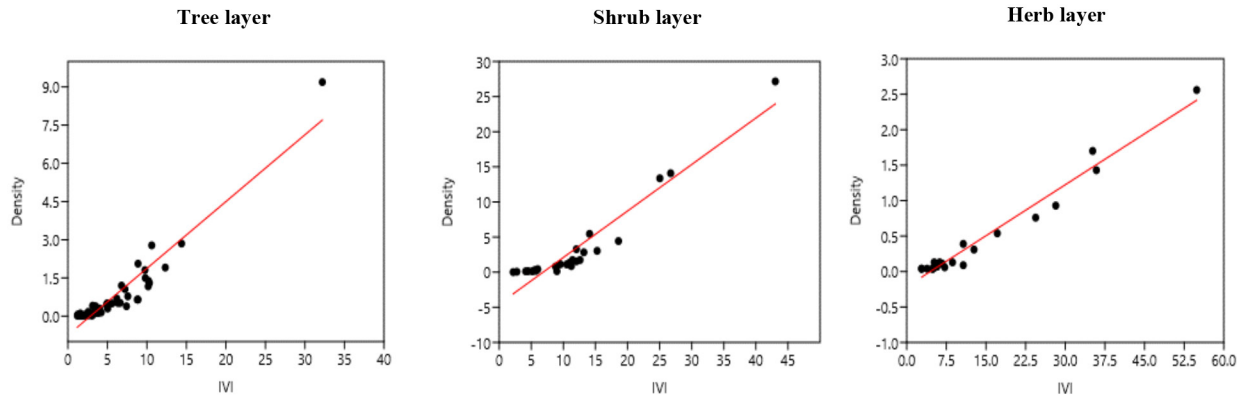


**Figure 3a** Density vs importance value index, *Atlantia monophyla* (Tree), *Lantana camara* (Shrub), *Abutilon indicum* (Herb) showing dominance in Mettupalyam Reserve Forest

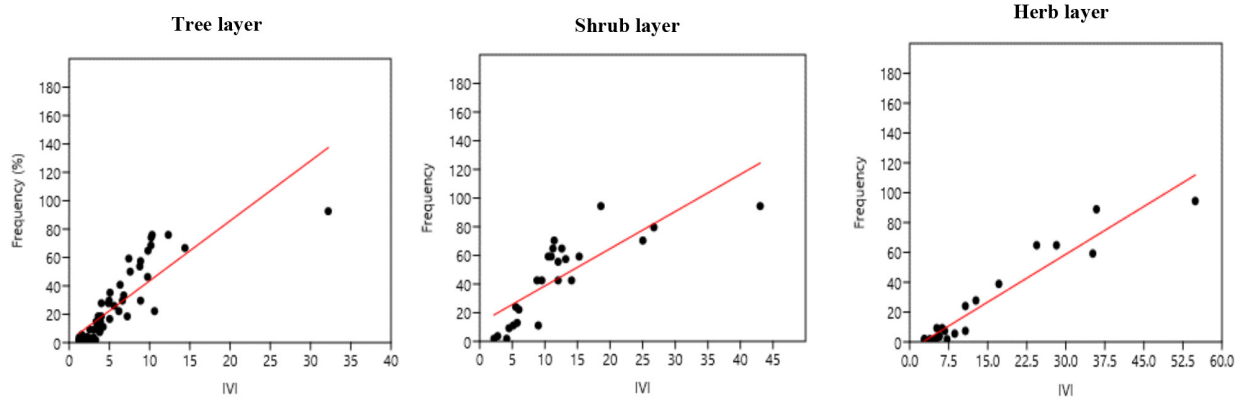


**Figure 3b** Frequency (%) vs importance value index, maximum frequency percentage shown by *Atlantia monophylla* (Tree), *Jasminum angustifolium* and *Lantana camara* (Shrub), *Abutilon indicum* and *Barleria prionitis* (Herb)

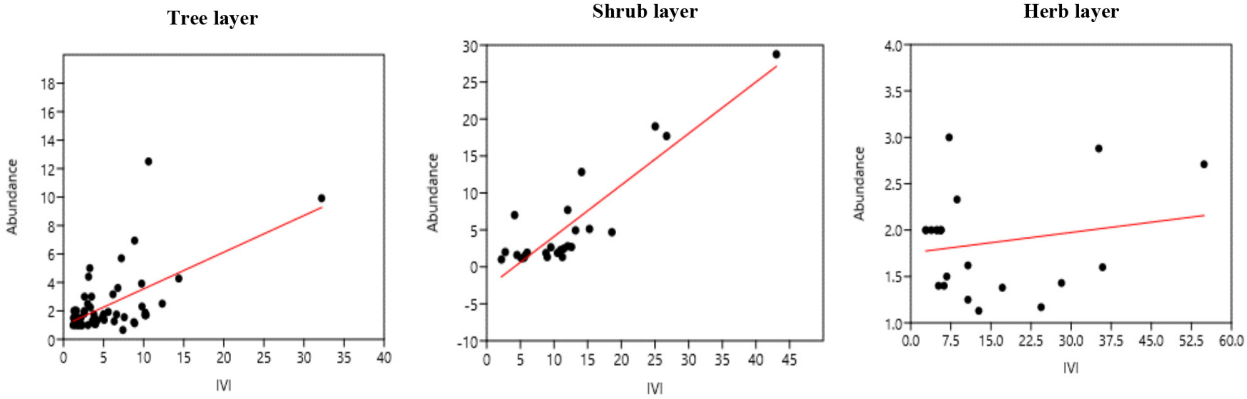


**Figure 3c** Abundance vs importance value index, maximum abundance shown by *Bambusa bambos* (Tree), *Lantana camara* and *Chromolaena odorata* (Shrub), *Ocimum tenuiflorum, Randia tomentosa, Abutilon indicum, Solanum trilobatum, Ageratum conyzoides, Argemone mexicanna, Dichondra repens, Euphorbia hirta, Heliotropium indicum, Mimosa pudica* and *Tribulus terrestris* (Herb). The maximum outliers observed in herb layer.

**Table 1** Phytosociological attributes of trees

| Sl. No | Tree | F | D | F (%) | A | IVI |
|---|---|---|---|---|---|---|
| 1. | *Acacia koenji* | Fabaceae | 0.11 | 5.56 | 2.00 | 1.56 |
| 2. | *Acacia leucophloea* | Fabaceae | 0.09 | 3.70 | 2.50 | 3.01 |
| 3. | *Acacia planifrons* | Fabaceae | 0.39 | 59.26 | 0.66 | 7.41 |
| 4. | *Aegel marmelos* | Rutaceae | 0.06 | 3.70 | 1.50 | 1.61 |
| 5. | *Aibizia lebbeck* | Fabaceae | 0.09 | 1.85 | 5.00 | 3.28 |
| 6. | *Ailanthus excelsa* | Simaroubaceae | 0.30 | 16.67 | 1.78 | 5.03 |
| 7. | *Ailanthus triphysa* | Simaroubaceae | 0.02 | 1.85 | 1.00 | 3.05 |
| 8. | *Alangium salvifolium* | Cornaceae | 0.41 | 9.26 | 4.40 | 3.13 |
| 9. | *Albizia amara* | Fabaceae | 1.81 | 46.30 | 3.92 | 9.75 |
| 10. | *Atlantia monophylla* | Rutaceae | 9.19 | 92.59 | 9.92 | 32.20 |
| 11. | *Azadirachta indica* | Meliaceae | 0.52 | 40.74 | 1.27 | 6.33 |
| 12. | *Bahunia racemosa* | Fabaceae | 0.65 | 57.41 | 1.13 | 8.87 |
| 13. | *Bamboosa bamboo* | Poaceae | 2.78 | 22.22 | 12.50 | 10.61 |
| 14. | *Butea monosperma* | Fabaceae | 0.02 | 1.85 | 1.00 | 1.97 |
| 15. | *Cassia fistula* | Fabaceae | 0.20 | 18.52 | 1.10 | 3.85 |
| 16. | *Cassia spectabilis* | Fabaceae | 0.04 | 1.85 | 2.00 | 1.39 |
| 17. | *Celtis philipensis* | Cannabaceae | 0.39 | 12.96 | 3.00 | 3.50 |
| 18. | *Chloroxylon swetinea* | Rutaceae | 2.85 | 66.67 | 4.28 | 14.38 |
| 19. | *Commiphora caudata* | Burseraceae | 0.15 | 11.11 | 1.33 | 4.22 |
| 20. | *Cordia gharaf* | Boraginaceae | 0.17 | 9.26 | 1.80 | 2.57 |
| 21. | *Dalbergia latifolia* | Fabaceae | 0.02 | 1.85 | 1.00 | 1.49 |
| 22. | *Dalbergia paniculata* | Fabaceae | 0.26 | 18.52 | 1.40 | 3.99 |
| 23. | *Delonix regia* | Fabaceae | 0.13 | 7.41 | 1.75 | 3.79 |
| 24. | *Diospyros montana* | Ebenaceae | 0.04 | 1.85 | 2.00 | 1.31 |
| 25. | *Erythroxylon monogynum* | Erythroxylaceae | 1.50 | 64.81 | 2.31 | 9.79 |
| 26. | *Glycosmis pentaphylla* | Rutaceae | 0.02 | 1.85 | 1.00 | 1.19 |
| 27. | *Gmelina arborea* | Lamiaceae | 0.50 | 29.63 | 1.69 | 4.96 |
| 28. | *Gyrocarpus americanus* | Hernandiaceae | 0.50 | 25.93 | 1.93 | 5.58 |
| 29. | *Hardwickia binata* | Fabaceae | 0.13 | 9.26 | 1.40 | 3.81 |
| 30. | *Holoptelea integrifolia* | Ulmaceae | 0.52 | 29.63 | 1.75 | 6.61 |
| 31. | *Limonia acidissima* | Rutaceae | 0.06 | 3.70 | 1.50 | 1.24 |
| 32. | *Mallotus philippensis* | Euphorbiaceae | 0.06 | 1.85 | 3.00 | 2.62 |
| 33. | *Morinda citrifolia* | Rubiaceae | 0.04 | 3.70 | 1.00 | 2.30 |
| 34. | *Morinda tinctoria* | Rubiaceae | 0.04 | 3.70 | 1.00 | 2.27 |
| 35. | *Muraya koenigii* | Rutaceae | 1.20 | 33.33 | 3.61 | 6.78 |
| 36. | *Phyllanthus embellica* | Phyllanthaceae | 0.33 | 14.81 | 2.25 | 3.35 |
| 37. | *Pongamia binata* | Fabaceae | 0.24 | 18.52 | 1.30 | 3.61 |
| 38. | *Premna tomentosa* | Lamiaceae | 0.48 | 35.19 | 1.37 | 5.07 |
| 39. | *Prosopis juliflora* | Fabaceae | 2.06 | 29.63 | 6.94 | 8.87 |
| 40. | *Pterocarpus marsupium* | Fabaceae | 0.43 | 27.78 | 1.53 | 4.89 |
| 41. | *Rhus mysorensis* | Anacardiaceae. | 0.30 | 27.78 | 1.07 | 4.00 |
| 42. | *Spathodea campanulata* | Bignoniaceae | 0.06 | 3.70 | 1.50 | 2.17 |
| 43. | *Sapindus emarginatus* | Sapindaceae | 1.91 | 75.93 | 2.51 | 12.32 |
| 44. | *Senegalia pennata* | Fabaceae | 1.39 | 74.07 | 1.88 | 10.19 |
| 45. | *Spondias mangifera* | Anacardiaceae | 1.17 | 68.52 | 1.70 | 10.16 |
| 46. | *Strychnos nux vomica* | Loganiaceae | 0.78 | 50.00 | 1.56 | 7.58 |
| 47. | *Syzygium cumini* | Myrtaceae | 0.17 | 14.81 | 1.13 | 3.88 |
| 48. | *Tamarindus indica* | Fabaceae | 0.65 | 53.70 | 1.21 | 8.78 |
| 49. | *Tectona grandis* | Lamiaceae | 1.06 | 18.52 | 5.70 | 7.22 |
| 50. | *Terminalia arjuna* | Combretaceae | 0.70 | 22.22 | 3.17 | 6.17 |
| 51. | *Terminalia chebula* | Combretaceae | 0.04 | 1.85 | 2.00 | 2.61 |
| 52. | *Vitex altissima* | Lamiaceae | 0.02 | 1.85 | 1.00 | 1.75 |
| 53. | *Wrightia tinctoria* | Apocynaceae | 0.07 | 3.70 | 2.00 | 1.62 |
| 54. | *Ziziphus glabrata* | Rhamnaceae | 1.30 | 75.93 | 1.71 | 10.31 |

F = family, D = density, F (%) = frequency (%), A = abundance, IVI = importance value index

**Table 2** Phytosociological attributes of shrubs

| Sl. No | Shrub | F | D | F (%) | A | IVI |
|---|---|---|---|---|---|---|
| 1. | *Calotropis procera* | Apocynaceae | 0.07 | 3.70 | 2.00 | 2.75 |
| 2. | *Carissa carandus* | Apocynaceae | 0.43 | 22.22 | 1.92 | 6.01 |
| 3. | *Carmona retusa* | Boraginaceae | 0.13 | 1.85 | 7.00 | 4.14 |
| 4. | *Cassia auriculata* | Caesalpinioideae | 0.80 | 42.59 | 1.87 | 8.80 |
| 5. | *Catunaregam spinosa* | Rubiaceae | 0.20 | 12.96 | 1.57 | 5.74 |
| 6. | *Chromolaena odorata* | Asteraceae | 13.37 | 70.37 | 19.00 | 25.03 |
| 7. | *Dodonaea viscosa* | Sapindaceae | 1.35 | 59.26 | 2.28 | 10.96 |
| 8. | *Euphorbia antiquorum* | Euphorbiaceae | 0.15 | 11.11 | 1.33 | 8.99 |
| 9. | *Euphorbia heterophylla* | Euphorbiaceae | 0.02 | 1.85 | 1.00 | 2.18 |
| 10. | *Euphorbia tirucalli* | Euphorbiaceae | 0.13 | 11.11 | 1.17 | 5.15 |
| 11. | *Flueggea leucopyrus* | Phyllanthaceae | 0.87 | 64.81 | 1.34 | 11.24 |
| 12. | *Grevilia hirsuta* | Proteaceae | 0.30 | 24.07 | 1.23 | 5.53 |
| 13. | *Hugonia mystax* | Linaceae | 1.56 | 55.56 | 2.80 | 12.03 |
| 14. | *Jasminum angustifolium* | Oleaceae | 4.43 | 94.44 | 4.69 | 18.59 |
| 15. | *Jatropha gossypifolia* | Euphorbiaceae | 1.74 | 70.37 | 2.47 | 11.43 |
| 16. | *Lantana camara* | Verbenaceae | 27.17 | 94.44 | 28.76 | 43.02 |
| 17. | *Opuntia littoralis* | Cactaceae | 1.11 | 59.26 | 1.88 | 10.52 |
| 18. | *Opuntia stricta* | Cactaceae | 0.15 | 9.26 | 1.60 | 4.50 |
| 19. | *Pavetta indica* | Rubiaceae | 5.46 | 42.59 | 12.83 | 14.09 |
| 20. | *Pterolobium hexapetalum* | Caesalpiniaceae | 3.04 | 59.26 | 5.13 | 15.26 |
| 21. | *Randia tomentosa* | Rubiaceae | 1.74 | 64.81 | 2.69 | 12.59 |
| 22. | *Solanum violaceum* | Solanaceae | 14.09 | 79.63 | 17.70 | 26.72 |
| 23. | *Glycosmis pentaphylla* | Rutaceae | 3.28 | 42.59 | 7.70 | 12.03 |
| 24. | *Toddalia asiatica* | Rutaceae | 2.83 | 57.41 | 4.94 | 13.19 |
| 25. | *Ziziphus oenoplia* | Rhamnaceae | 1.13 | 42.59 | 2.65 | 9.52 |

F = family, D = density, F (%) = frequency (%), A = abundance, IVI = importance value index

recorded in *Abutilon indicum* (2.56) followed by *Randia tomentosa* (1.70), *Barleria prionitis* (1.43) and *Sida cordifolia* (0.93) which were commonly distributed whereas the lowest density was observed in *Centella asiatica*, *Dichondra repens, Euphorbia hirta*, *Heliotropium indicum* and *Mimosa pudica* with the density of 0.04 (Figure 3a). The species with high frequency in the forests was *Abutilon indicum* (94.44%) followed by *Barleria prionitis* (88.89%) and *Sida cordifolia* (64.81%) (Figure 3b). The high number of individuals per unit area could be due to the rapidly distributed seeds by wind and other combine factors like dormancy, germination capacity, soil moisture content and survival of fitness. Six species such as *Centella asiatica, Dichondra repens, Euphorbia hirta, Heliotropium indicum, Mimosa pudica* and *Ocimum tenuiflorum* registered low frequency of 1.85% in the forest. *Ocimum tenuiflorum* had higher abundance (3.00) whereas *Parthenium hysterophorus* showed lower abundance (1.13) in the forests (Figure 3c). The maximum important value index of herb species was recorded in *Abutilon indicum* (54.87), *Barleria prionitis* (35.88), *Randia tomentorum* (35.18) and *Sida cordifolia* (28.20) while minimum percentage was observed in two species such as *Heliotropium indicum* and *Mimosa pudica* (2.82) (Table 3). In the herb layer, higher dominance was shown by *Abutilon indicum* (Figure 3a) which was due to survival, establishment and vigorous growth pattern of this species. The similar finding was observed by Mohamed and Al-Shehri (2015) for Kanawa forest.

**Table 3** Phytosociological attributes of herbs

| Sl. No | Herb | F | D | F (%) | A | IVI |
|---|---|---|---|---|---|---|
| 1. | *Abutilon indicum* | Malvaceae | 2.56 | 94.44 | 2.71 | 54.87 |
| 2. | *Acalypha indica* | Euphorbiaceae | 0.76 | 64.81 | 1.17 | 24.39 |
| 3. | *Ageratum conyzoides* | Asteraceae | 0.07 | 3.70 | 2.00 | 5.64 |
| 4. | *Argemone mexicanna* | Papaveraceae | 0.07 | 3.70 | 2.00 | 5.64 |
| 5. | *Barleria prionitis* | Acanthaceae | 1.43 | 88.89 | 1.60 | 35.88 |
| 6. | *Centella asiatica* | Apiaceae | 0.04 | 1.85 | 2.00 | 4.90 |
| 7. | *Cissus quadrangularis* | Vitaceae | 0.09 | 7.41 | 1.25 | 10.70 |
| 8. | *Commelina benghalensis* | Commelinaceae | 0.54 | 38.89 | 1.38 | 17.14 |
| 9. | *Dichondra repens* | Convolvulaceae | 0.04 | 1.85 | 2.00 | 4.90 |
| 10. | *Digera arvensis* | Amaranthaceae | 0.11 | 7.41 | 1.50 | 6.73 |
| 11. | *Euphorbia geniculata* | Euphorbiaceae | 0.13 | 9.26 | 1.40 | 6.23 |
| 12. | *Euphorbia hirta* | Euphorbiaceae | 0.04 | 1.85 | 2.00 | 3.86 |
| 13. | *Heliotropium indicum* | Boraginaceae | 0.04 | 1.85 | 2.00 | 2.82 |
| 14. | *Ipomoea nil* | Convolvulaceae | 0.39 | 24.07 | 1.62 | 10.70 |
| 15. | *Medicago denticulata* | Fabaceae | 0.13 | 9.26 | 1.40 | 5.19 |
| 16. | *Mimosa pudica* | Fabaceae | 0.04 | 1.85 | 2.00 | 2.82 |
| 17. | *Ocimum tenuiflorum* | Lamiaceae | 0.06 | 1.85 | 3.00 | 7.18 |
| 18. | *Parthenium hysterophorus* | Asteraceae | 0.31 | 27.78 | 1.13 | 12.72 |
| 19. | *Randia dumetorum* | Rubiaceae | 1.70 | 59.26 | 2.88 | 35.18 |
| 20. | *Sida cordifolia* | Malvaceae | 0.93 | 64.81 | 1.43 | 28.20 |
| 21. | *Solanum trilobatum* | Solanaceae | 0.13 | 5.56 | 2.33 | 8.65 |
| 22. | *Tribulus terrestris* | Zygophyllaceae | 0.07 | 3.70 | 2.00 | 5.64 |

F = family, D = density, F (%) = frequency (%), A = abundance, IVI = importance value index

## Grass layer

In the grass layer, *Oplismenus burmannii* showed maximum density (19.34%) followed by *Apluda mutica* (9.10%), *Chrysopogon aciculatus* (8.06%), *Cynodon dactylon* (7.43%), *Heteropogon contortus* (7.52%) whereas *Melinis repens* registered minimum density (0.18%) (Table 4). The buried grass seeds could survive in soil for long period of time and germinate under favourable climatic conditions. Moreover, these grasses spread through rhizomes and interconnected extensive root systems which contributed to their rapid growth and propagation. Consistent result was observed by Khanduri et al. (2017) for *Apluda mutica, Anaphalis busua* and *Echinochloa colona* in Garhwal, Himalaya.

## Species diversity and Evenness Index

Among the four different flora habit types, tree layer registered maximum taxa of 54 followed by shrub layer at 25, grass layer at 24 and herb layer at 22. The expected species richness was similar to the observed species richness except for the tree layer at 55.67. The highest Margalef species richness, was observed in tree layer as 6.94, followed by herb layer at 3.36, grass layer at 3.16 and shrub layer at 2.84. The number of individuals more than 1000 were in tree layer, shrub layer and grass layer while it was lowest in herb layer. Species dominance was low in tree layer at 0.09 and grass layer at 0.08 as compared to herb layer at 0.14 which led to increase species diversity index. Furthermore, species diversity and similarity index were found high in tree layer and grass layer. The highest Simpson index was observed in grass layer (1-D = 0.92), tree layer (1-D = 0.91), herb layer (1-D = 0.86) and shrub layer (1-D = 0.84). The maximum Shannon D index (H = 3.08) was observed in tree layer, followed by grass layer (H = 2.76), herb layer (H = 2.28) and shrub layer (H = 2.25) respectively. The species evenness index revealed less evenness

**Table 4** Density of grasses in the reserve forest

| SI. No | Grass | Density (%) |
|---|---|---|
| 1. | *Alloteropsis cimicina* | 5.30 |
| 2. | *Apluda mutica* | 9.10 |
| 3. | Arachne racemose | 7.05 |
| 4. | *Aristida setacea* | 0.64 |
| 5. | *Brachiaria semiundulata* | 3.18 |
| 6. | *Bromus diandrus* | 0.28 |
| 7. | *Bulbostylis barbata* | 5.53 |
| 8. | *Chloris barbata* | 1.49 |
| 9. | *Chloris virgata* | 0.92 |
| 10. | *Chrysopogon aciculatus* | 8.06 |
| 11. | *Cynodon dactylon* | 7.43 |
| 12. | *Cyperus rotundus* | 2.95 |
| 13. | *Dichanthium aristatum* | 5.19 |
| 14. | *Digitaria ciliaris* | 2.50 |
| 15. | *Digitaria longifolia* | 2.15 |
| 16. | *Enteropogon monostachyus* | 6.20 |
| 17. | *Eragrostiella bifaria* | 2.46 |
| 18. | *Eragrostis cilianensis* | 0.27 |
| 19. | *Heteropogon contortus* | 7.52 |
| 20. | *Hyparrhenia hirta* | 0.80 |
| 21. | *Melinis repens* | 0.18 |
| 22. | *Oplismenus burmannii* | 19.34 |
| 23. | *Perotis indica* | 0.71 |
| 24. | *Themeda triandra* | 0.77 |

**Table 5** Different diversity indices for Mettupalayam Reserve Forest

| Diversity indices | Trees | Shrubs | Herbs | Grasses |
|---|---|---|---|---|
| SR | 54.00 | 25.00 | 22.00 | 24.00 |
| In | 2071.00 | 4619.00 | 522.00 | 1460.00 |
| D | 0.09 | 0.17 | 0.14 | 0.08 |
| 1-D | 0.91 | 0.84 | 0.86 | 0.92 |
| H | 3.08 | 2.25 | 2.28 | 2.76 |
| J | 0.40 | 0.38 | 0.45 | 0.66 |
| Dmg | 6.94 | 2.84 | 3.36 | 3.16 |
| BP | 0.24 | 0.32 | 0.26 | 0.17 |
| Chao-1 | 55.67 | 25.00 | 22.00 | 24.00 |

SR = observed species richness, ln = natural logarithm, Chao-1 = expected species richness to estimate total richness at a site, 1-D = Simpson index, H = Shannon index, J = Evenness index, Dmg = Margalef index, BP = Berger-Parker dominance.

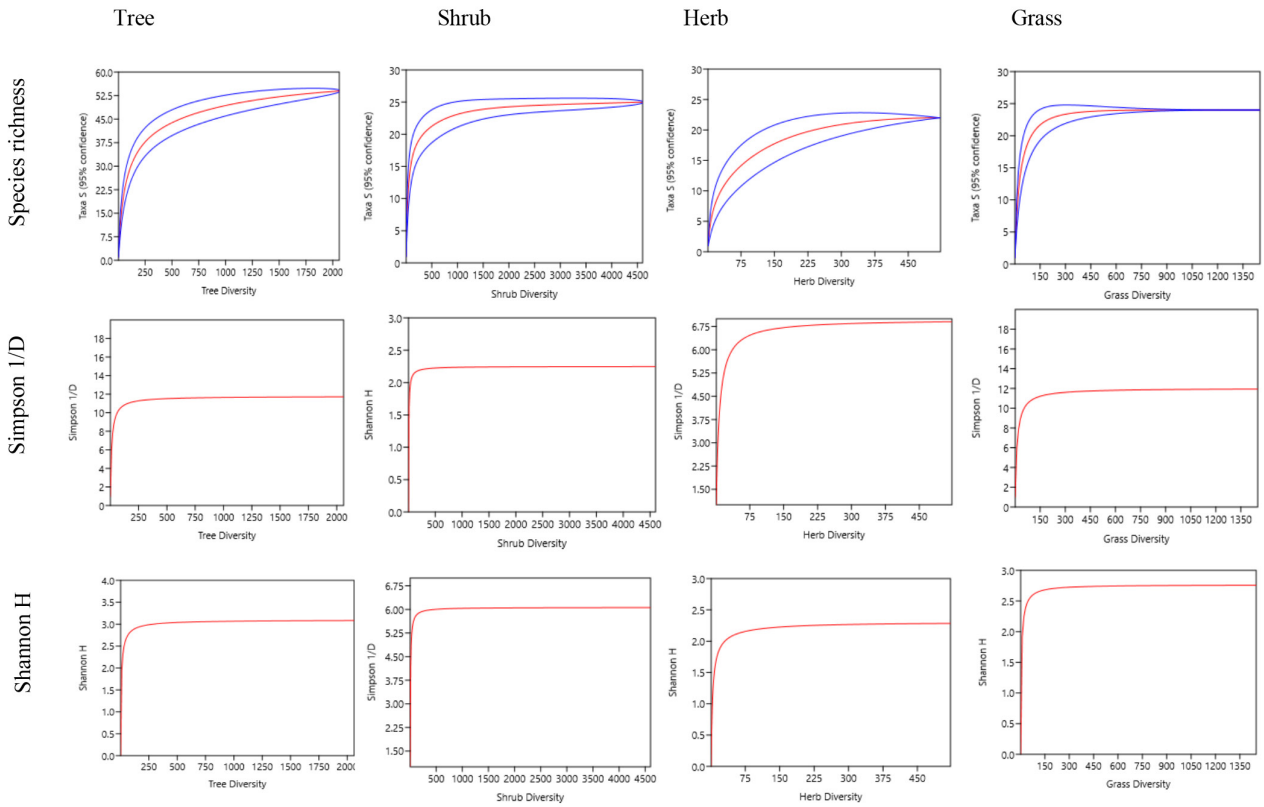


**Figure 4** Species accumulation curve shows diversity index of Mettupalayam Reserve Forest

in grass layer (J = 0.66), herb layer (E = 0.45), tree layer (J = 0.40) and shrub layer (J = 0.38) which indicated the recorded species were not evenly distributed in the forest and were moderately distributed in all sites of the forest. The species richness was more in tree layer when compared to other three layers. Higher species richness may be contributed to location, soil characteristics, soil type, and climatic conditions which in turn increased the species diversity. The results were in concurrent with the findings of Timilsina et al. (2007) which observed that the number of species in tree layer was high in Sal Forest in the western Terai of Nepal.

Species accumulation curve showed diversity indices of flora in Mettupalayam Reserve Forest (Figure 4). In comparison to the other three layers, the tree layer diversity perspective may be more in terms of Shannon index of diversity values ranged from 2.25 to 3.08 (Figure 4). The present findings showed contrast with the result of Okechalu et al. (2021) which recorded the Shannon value fluctuated from 1.57 to 2.17 for Pandam Wildlife Park. The Simpson index showed a ranged from 0.84 to 0.92 and it was consistent with the work of Abdullahi (2010), Abba et al. (2015), Ogunjemite (2017), Ikyaagba et al. (2019) and Sahu et al. (2019) respectively.

## CONCLUSION

Corridor management and conservation requires authenticate and consistent information on structural composition of flora and their diversity pattern. This is the pioneer research on cataloguing flora in Mettupalayam Reserve Forest. Floral composition and stand structure serving as important indicators in the formation of protection measures. This study provides scientific and baseline information on the availability of flora and its distribution pattern. Hence, it will used for management and protection of native species.

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