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Floristic diversity along an altitudinal gradient of Mannavan Shola forest in Southern Western Ghats of Kerala.

Authors:
Binu Thomas[1], Chandrashekara UM[2] and Rajendran A[1].

Institution:
1. Department of Botany, School of Life Sciences, Bharathiar University, Coimbatore 641 046. Tamil Nadu.
2. Kerala Forest Research Institute Sub Centre, Chandakunnu P.O. Nilambur- 679 342.

Corresponding author:
Binu Thomas

Email:
binuthomasct@gmail.com

ABSTRACT:

The present study was carried to assess the variability in the species diversity using appropriate quantities and statistical analysis along the altitudinal gradients in the Mannavan shola forest in Kerala. The analysis of species diversity revealed that, the maximum species diversity greater in the low altitudinal gradient followed by middile. The dominant species are *Hydnocarpus alpina, Isonandra stocksii, Gomphandra coriaceae and Mastixia arborea* in Altitude-I (1900 msl), *Litsea wightiana, Ilex wightian and Turpinia nepalensis* are dominant in both Altitude-II (2100 msl) and Altitude-III(2300msl). *Persea macrantha, Phoebe lanceolata, Cinnamomum sulphuratum, Syzygium densiflorum, Turpinia nepalensis, Litsea wightiana, Neolitsea scrobiculata and Cinnamomum species* are common to all altitudinal gradients. The value of similarity index reveals that the middle (2100msl) and higher altitudes (2300msl) have more number of similar species (51%) than lower (1900msl) and middle (42%), lower and higher (28%) altitudinal gradients respectively. The shola forests are of unique that harbours 20 % of listed tree species, which are endemic to the Southern Western Ghats of Kerala.

Keywords:
Mannavan Shola forest, Altitudinal gradients analysis, Southern Western Ghats of Kerala.

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INTRODUCTION

The shola forest which occurs in the southern peninsular India at altitudes beyond 1700-1800 m is also designated as tropical montane rain forests (Butt Davy, 1938). The shola ecosystem is characterized by distinct vegetation patches associated with vast expanses of grass lands, the tree cover of the forest type is often much restricted in its distribution , often confined to sheltered ravines, troughs and other depressions of the ghat (Blasco,1971). The community structure of shola forests varies with altitudinal gradients. The shola forests are characterized by having stunted evergreen trees with dense, round or umbrella shaped crowns consisting of entire and coriacious leaves. Moreover, trees are clothed and festooned with rich mass of epiphytes (Champion, 1936; Blasco, 1971).

Floristic information on the shola vegetation type are found in earlier works like Wight (1838-53), Hooker (1872-97), Gamble and Fischer (1915-36) and other regional and local floras. Perhaps the floristic account on the high altitude forests of Kerala is available in publications of Shetty and Vivekananthan (1968) and Sebastine and Vivekananthan (1967). From the point of view of biodiversity, shola forests regarded as unique due to rich flora and fauna, particularly rare and endemic elements (Blasco, 1970, Jose *et al*., 1994).

The variation in species diversity can be linked to several ecological gradients (Grime, 1979; Palmer, 1992; Huston & De Angelis, 1994). Altitudinal gradient is well known to be one of the decisive factors in the spatial patterns of floristic diversity (Szaro, 1989; Lieberman, *et al*., 1996; Zimmerman *et al*., 1999; Brown 2001; Lomolino, 2001).

Study Area and Climate

The Mannavan shola forest (77° 12¢ 8" E and 10° 12¢ 8" N). Comes under Marayoor Forest Range of Wild life Division (Munnar, Idukki District, and Kerala). This shola forest is nearly 370 ha in size with an average elevation of 1950 m. The mean annual temperature is about 20° C and mean annual precipitation is 2000 mm-3000 mm. The soil is red, sandy loam, oxysol, acid (pH = 4.2) with 4.6 % to 14 % Organic carbon content.

MATERIALS AND METHODS

Field surveys were undertaken from September 2007- April 2008, to assess and document the floristic diversity of the Mannavan Shola forest (Anamudi shola National Park). A Trimble GEOXT 2005 (Terrasyn^{TM} software) was used to segregate the study area into three altitudinal ranges with 200 m increment *i.e.*, from 1900, 2100, and 2300 msl respectively. Above the 2500 m altitude the area is covered with vast stretches of grasslands associated with small shola patches. Among the three permanent plots, two of them have 1 ha in size and third one has 0.5 ha in size respectively. Each 1 ha plot was in turn subdivided into 100 quardrats, each of 10×10 m in size. All mature trees (gbh > 30.1 cm), saplings (gbh- 10.1cm to 30.0 cm) and tree seedlings (girth < 10.0 cm, height < 1.0 m) were tagged. The plant species were identified by consulting floras like, Flora of the presidency of Madras (Gamble and Fischer, 1915-1936) and Field key to the trees and lianas of the evergreen forests of the Western Ghats (Pascal and Ramesh, 1987).

Vegetation Analysis

Three distinct altitudinal gradients were selected at Mannavan Shola forest (Anamudi Shola National Park) with 200 m intervals (1900, 2100 and 2300 msl). The floristic diversity in each altitudinal gradients with number and occurrence of all trees in each quadrat were measured. Girth at breast height (gbh at 1.37 m above groud) of all trees and saplings were also recorded. For trees with large buttresses the girth was measured above the buttressed part.

The vegetation data were analysed for relative density, relative frequency and relative dominance (Phillips, 1959) and the sum of the values for these parameters were represented by Importance Value Index (IVI) for various species (Curtis, 1959).

Relative density =

$$\frac{\text{Total no. of individuals of a species}}{\text{Total no. of individuals of all species}} \times 100$$

Frequency =

$$\frac{\text{No.of quardrats in which a species found}}{\text{No.of quardrats studied}} \times 100$$

Relative frequency =

$$\frac{\text{Frequency of a given species}}{\text{Sum of frequency of all species}} \times 100$$

Relative dominance =

$$\frac{\text{Total basal area of a given species}}{\text{Total basal area of all species}} \times 100$$

Important Value Index (IVI) = Relative density + Relative frequency + Relative dominance

Species diversity was calculated using a formula given by Shannon and Wiener (1963) as;

$$H = -\sum \{(ni/N) \quad \ln (ni/N)\}$$

Where, 'H' is Shannon index of general diversity, 'ni' is the importance value index of species 'i' and 'N' is importance value index in the community.

Sorensons's similarity Index (Mishra, 1989) was calculated for comparing the vegetation of each altitudinal gradients of a given shola forest.

Similarity Index = 2C/A+B

Where,'C' is the total number of common species of plot I and plot II, 'A' is the total number of species in plot I and 'B' is the total number of species in plot II.

RESULT AND OBSERVATION

Altitude-1 (1900 msl)

There were a total of 554 individuals of mature trees belonging to 40 species, 34 genera and 21 families distributed in quadrats studied (1 ha^{-1}) in Altitude I. *Hydnocarpus alpina* had the largest density of 115 ha^{-1} and relative density of 21.14 % followed by *Isonandra stocksii, Gomphandra coriaceae and Mastixia arborea* had density 64 $ha^{-1,}$ 63 ha^{-1}, 59 ha^{-1} and relative densities of 11.76 %, 11.58 % and 10.85 % respectively. All other species had relative density less than 10 percent.

Total basal area of all species was 50.5735 $m^2 ha^{-1}$ at altitude I. Largest basal area of 8.8301 m^2ha^{-1} and relative basal area of 17.46 % were in case of *Hydnocarpus alpina*. This was followed by *Isonandra stocksii* which had basal area of 8.3948 $m^2 ha^{-1}$ and relative basal area of 16.59 percent. *Syzygium densiflorum* which had basal area of 3.8499 m^2ha^{-1} and relative basal area of 10.75 percent. *Cinnmomum sulphuratum, Persea macrantha and Actinodaphne bourdillonii* had relative basal area greater than 5 % each. Species like *Elaeocarpus serratus, Cryptocarya lawsonii, Litsea wightiana, Phoebe lanceolata, Glochidion neilgherrense, Celtis philippensis etc*., had relative basal area less than 1% each. *Hydnocarpus alpina* had the maximum percentage of frequency of 16.48, followed by *Isonandra stocksii* with percentage of frequency of 10.97. *Syzygium densiflorum ,Cinnmomum sulphuratum, Persea macrantha and Actinodaphne bourdillonii* had RF (Relative frequency) greater than 5 % each. Relative importance value (RIVI) was largest (18.35) in case of *Hydnocarpus alpina*. Species like *Isonandra stocksii, Syzygium densiflorum, Cinnmomum sulphuratum, Persea macrantha and Actinodaphne bourdillonii* had RIVI of 13.11, 8.53, 8.44, 7.90 and 6.94 respectively. *Cryptocarya lawsonii*, *Phoebe lanceolata*, *Glochidion neilgherrense*, *Celtis philippensis etc.,* had RIVI less than one percent each.

Largest FRD (Frequency of distribution) of 20.35 % was observed in Lauraceae followed by 20.18 % in Flacourtiaceae and 11.75 % in Icacinaceae. Largest RBA (Relative basal area) of 29.23 % was noticed in Lauraceae followed by 17.46 %, 16.59 % and 12.36 % in Flacourtiaceae, Sapotaceae and Myrtaceae respectively. Largest RF (Relative frequency) of 33.65 % was noticed in Lauraceae followed by 16.47 %, 12.89% and 10.98% in Flacourtiaceae, Myrtaceae and Sapotaceae. All other families had RF of less than 5 % each. RIVI was largest in Lauraceae (32.45) followed by Flacourtiaceae (18.36), Sapotaceae (13.11) and Myrtaceae (10.71). All other families had RIVI less than 5 each.

Altitude-II (2100 msl)

There were, a total density of the vegetation of mature trees and was identified as 552 individuals belonging to 31 species, 21genera and 15 families with quardrats studied studied (ha^{-1}) in Altitude II. *Litsea wightiana* had the largest density of 125 ha^{-1} and relative density 22.64 %. All other species had relative density less than 10 percent.

Total basal area of all species was 46.8099 $m^2 ha^{-1}$ at altitude II. Largest basal area of 9.7020 m^2 ha^{-1} and relative basal area of 20.73 % were in case of *Ilex wightiana*. This was followed by *Syzygium densiflorum*, *Syzygium malabaricum, Alseodaphne semicarpifolia and Cinnamomum sulphuratum* had basal areas of 4.1051 m^2 ha^{-1}, 3.9861 m^2 ha^{-1}, 2.7508 $m^2 ha^{-1}$and 2.6998 $m^2 ha^{-1}$ and relative basal areas of 8.77, 8.52, 5.88 and 5.77 percent respectively. All other species had relative basal area less than 5 percent. Species like *Actinodaphne bourdillonii, Celtis tetrandra, Cinnamomum malabaricum, Vaccinium leschnaultii etc.,* had relative basal area less than 1% each. *Litsea wightiana* had the maximum percentage of frequency of 15.69 followed by *Alseodaphne semicarpifolia* with percentage frequency of 9.31. Species like *Turpinia nepalensis, Neolitsea scrobiculata, Beilschmiedia wightii, Syzygium malabaricum* and *Ilex wightiana* had RF greater than 5% each. All other species had RF less than 5 % each.

Relative Importance Value (RIVI) was largest (15.59) in case of *Litsea wightiana*, *Ilex wightiana, Alseodaphne semicarpifolia* and

Turpinia nepalensis had RIVI of 10.72, 8.20 and 7.11 respectively. *Isonandra lanceolata*, *Syzygium montanum, Myrisine wightiana, Isonandra stocksii etc.,* had RIVI less than one each.

Largest FRD (Frequency of distribution) of 64.85% was observed in Lauraceae followed by 10.02 % in Staphylaceae and 8.01 % in Myrtaceae. Largest RBA of 48.07 was noticed in Lauraceae followed by 20.73 % and 18.67 % in Aquifoliaceae and Myrtaceae respectively. Largest RFof 61.53% was noticed in Lauraceae followed by 10.06 %, 8.58 % and 5.64 % in Myrtaceae, Staphylaceae and Aquifoliaceae. All other families had RF of less than 5% each. RIVI was largest in Lauraceae (58.01). Followed by Myrtaceae(12.16), Aquifoliaceae(10.72) and Staphylaceae (7.11). All other families had RIVI less than 5 each.

Altitude-III (2300 msl)

There were a total density of the vegetation of mature trees and was identified as 234 individuals belonging to 24 species, 21genera and 13 families with quardrats studied (0.5 ha^{-1}) in Altitude III. *Turpinia nepalensis* had the largest density of 43 $ha^{-0.5}$ and relative density of 18.38 %. Foillowed by *Ilex wightiana* and *Litsea wightiana* had densities of 29 $ha^{-0.5}$ and 28 $ha^{-0.5}$, and relative densities of 12.39 % and 11.97 % respectively. All other species had relative density less than 10 percent.

Total basal area of all species was 22.5360 m^2 $ha^{-0.5}$ at altitude III. Largest basal area of 4.9583 m2 $ha^{-0.5}$ and relative basal area of 22.00 % were in case of *Ilex wightiana*, this was followed by *Syzygium malabaricum* which had basal area of 4.8044 m^2 $ha^{-0.5}$ and relative basal area of 21.32 percent. *Turpinia nepalensis* which had basal area of 2.2338 m^2 $ha^{-0.5}$ and relative basal area of 9.91 percent. All other species had relative basal area less than 2 percent. *Turpinia nepalensis* had the maximum percentage frequency of 15.79 followed by *Ilex wightiana* and *Litsea wightiana* with RF of 11.70 % each. *Syzygium malabaricum, Rhododendron neilgiricum, Cinnmomum sulphuratum* and *Daphiniphyllum neilgherrense* had RF greater than 5 percent. All other species had RF less than 5 % each. RIVI was largest (15.36) in case of *Ilex wightiana* followed by *Turpinia nepalensis, Syzygium malabaricum* and *Litsea wightiana* had RIVI of 14.69, 13.16 and 9.44 respectively. *Elaeocarpus recurvatus*, *Persea macrantha, Isonandra lanceolata, Vibrunum coriaceum* had RIVI less than one each.

Largest FRD of 20.36 % was observed in Lauraceae followed by 19.46 %, 14.03 % and 12.67 % in Staphylaceae, Myrtaceae and Aquifoliaceae. All other families had FRD less than 10 percent. Largest RBA 27.32 % was noticed in Myrtaceae followed by 22.00 %, 14.26 % and 9.91 % in Aquifoliaceae, Lauraceae and Staphylaceae respectively. All other families had RBA less than 5 percent each. RIVI was largest in Myrtaceae (55.46), followed by Lauraceae (54.12), Aquifoliaceae (46.09), Staphylaceae (44.08), Ericaceae (19.73), Euphorbiaceae (15.85) and Oleaceae (13.19). All other families had RIVI less than10 percent.

Relationship between altitudinal gradients and mature tree species distribution

The number of species with respect to each altitudinal gradient shows that the maximum number of species were found in 1900 msl (40 species belonging to 34 genera and 21 families) followed by 2100 msl (31 species belonging to 21 genera and 15 families) and 2300 msl (24 species, 14 genera and 13 families). The reduction in species in higher altitudinal gradients could be attributed to ecophysiological constraints such as pattern of temperature, size of the forest cover, short period of

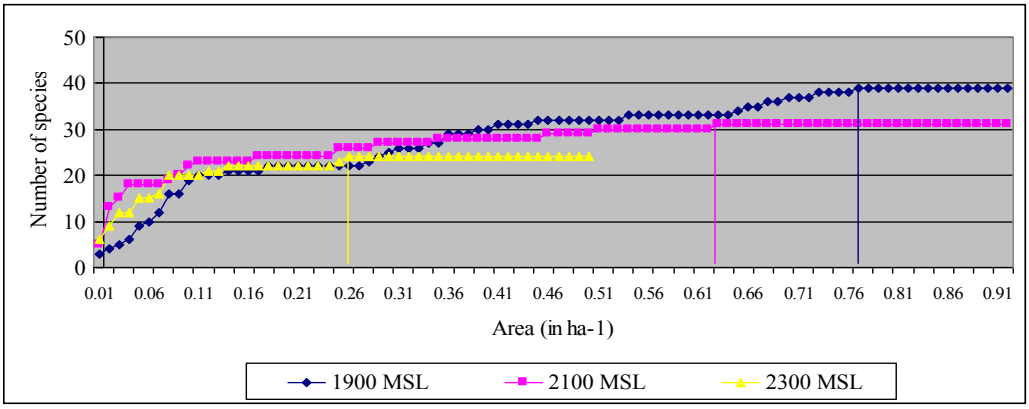

Fig.1 Relationship between altitudinal gradient with respect to species area curve

Table: 1 Common species and their Density, Basal area and IVI with respect to altitudinal gradients 1900 msl 2100 msl 2300 msl

Si No.	Name of sps.	D	BA	IVI	D	BA	IVI	D	BA	IVI
1	*c. sulphuratum*	12	2.058	25.32	14	2.699	11.74	9	1.97	17.88
2	*L. wightiana*	1	0.203	2.204	125	3.945	46.76	28	1.049	28.30
3	*N. scrobiculata*	1	0.12	0.634	32	1.60	16.3	2	0.12	2.57
4	*P. macrantha*	17	2.74	23.69	19	2.30	12.7	2	0.02	2.15
5	*P. lanceolata*	5	0.101	2.074	27	2.128	14.34	1	0.08	1.048
6	*S. densiflorum*	11	3.84	25.610	10	4.105	13.03	9	1.021	12.45
7	*T. nepalensis*	6	0.215	3.937	55	1.306	21.33	43	2.23	40.7

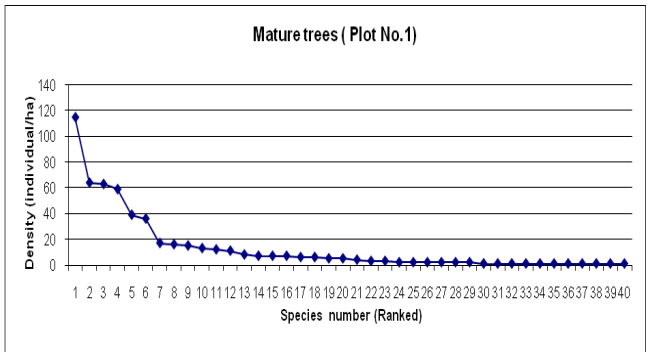

Fig: 2 Density rank analysis of Mature trees in Altitude I (1900 msl)

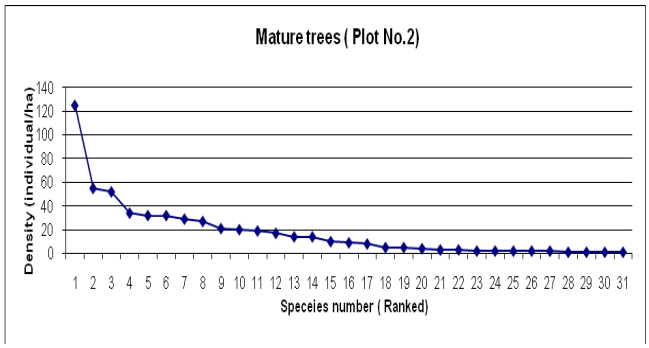

Fig: 3 Density rank analysis of Mature trees in Altitude II (2100 msl)

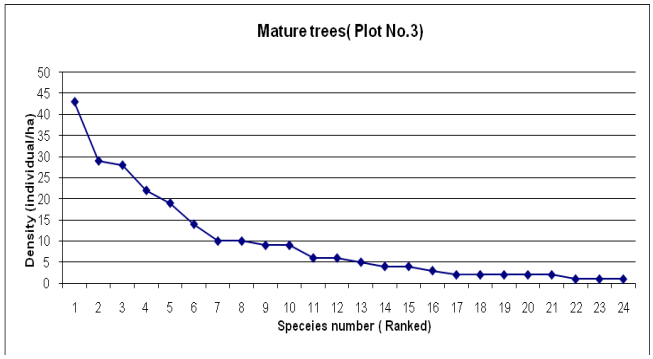

Fig: 4 Density rank analysis of Mature trees in Altitude III(2300)

growing season and other geographical barriers (Chawla *et al*.,2008).

In 1900 msl, the maximum distribution of species up to an area of 0.77 sq m ha^{-1} followed by 2100 msl, the distribution of species up to an area of 0.63 sq m ha^{-1} and 0.25 sq m $ha^{-0.5}$ in 2300 msl. The species like *Persea macrantha, Syzygium densiflorum, Cinnmomum sulphuratum, Turpinia nepalensis, Phoebe lanceolata, Litsea wightiana and Neolitsea scrobiculata* are common to all altitudinal gradients. The values of similarity index shows that Altitude II (2100 msl) and Altitude III (2300 msl) have more number of similar species (51 %) than Altitude I (1900 msl) and Altitude III (0.28 %) and Altitude I and Altitude II (42 %).

The lower species richness at the highest altitudinal gradient might be due to the loss of habitat diversity, extreme environmental conditions and lack of adaptability of species to sustain life in hostile climates (Clowell and Hurtt ,1994) Bhattarai and Vetaas,2003).

The AF (Abundance frequency) value shows that 43 % mature trees shows regular type of distribution followed by 12 % and 45 %, it was random and contigenous pattern of distribution in Altitude I. The AF value of Altitude II shows that 29 %, 20 % and 51 % of individuals and shows regular, random and contigenous pattern of distributions respectively, while in Altitude III 33 %, 12 % and 55 % of individuals were regular, random and contigenous pattern of distributions respectively.

In Altitude I (1900 msl), the maximum distribution of families up to an area of 0.45sq m. Followed by 0.85 Sq m and 0.12 sq m in both Altitude II and Altitude III respectively. The maximum distribution of families was found in the middle altitudinal gradient (2100 msl). The families like Lauraceae (116 families's ha^{-1}), Flacourtiaceae (115 families ha^{-1}) and Icacinaceae (67 families ha^{-1}) are dominant in 1900 msl. Followed by

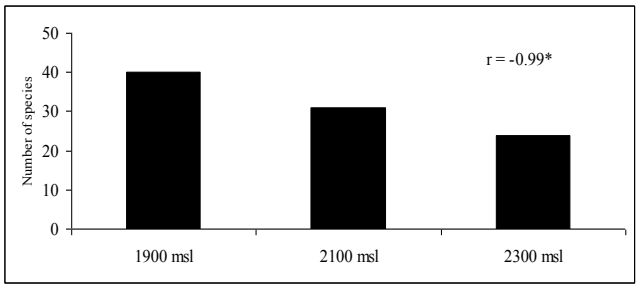

Fig: 5 Distribution of number of tree species with increasing altitude.

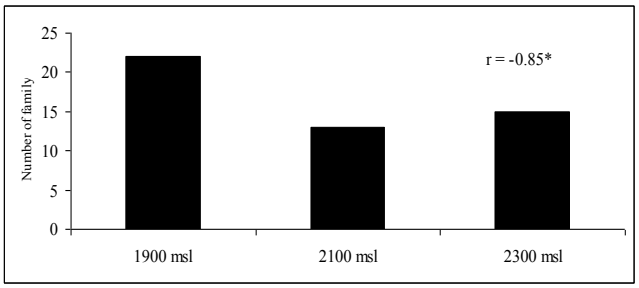

Fig: 7 Distribution of number of families (trees) with increasing altitude.

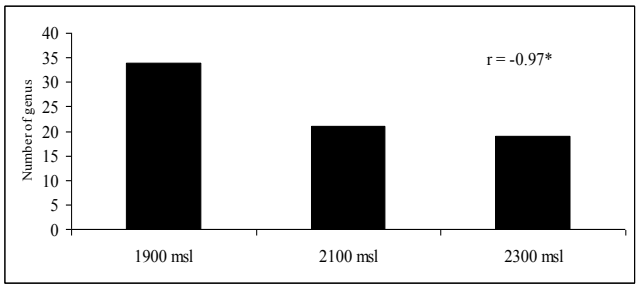

Fig: 6 Distribution of number of genus (trees) with increasing altitude.

Table: 2 Girth class distributions of mature trees along an altitudinal gradient.

Girth Classes	1900 msl	2100msl	2300msl
Class A	187	282	81
Class B	128	118	50
Class C	81	49	48
Class D	78	36	28
Class E	48	22	11
Class F	32	45	16
Total No. of species	554	552	234

Lauraceae (356 families ha^{-1}), Staphylaceae (55 families ha^{-1}) and Myrtaceae (44 families ha^{-1}) in 2100 msl and Lauraceae (45 families ha$^{-0.5}$), Staphylaceae (43 families ha$^{-0.5}$) and Myrtaceae (28 families ha$^{-0.5}$) in 2300 msl respectively.

Relationship between Girth class distribution of mature trees and altitudinal gradients

The girth class distribution of mature tree species with respect to each altitudinal gradients shows that more representations (282 individuals ha $^{-1}$) by the individuals of girth class 30.1 to 60.0 cm in 2100 msl. This indicates that more number of individuals has been regenerated to mature tree phase in 2100 msl than other extreme ends (1900 msl-2300msl). While more representations (128 individuals ha $^{-1}$) by the individuals of ghirth class 60.1 to 90.0 cm in 1900 msl and maximum representations (45 individuals ha $^{-0.5}$) by the individuals of girth class >180.1 cm in 2300 msl respectively.

Relationship between altitudinal gradient and endemic taxa

A total of 19 species endemic to Western Ghats of peninsular India. Which account for 21 %

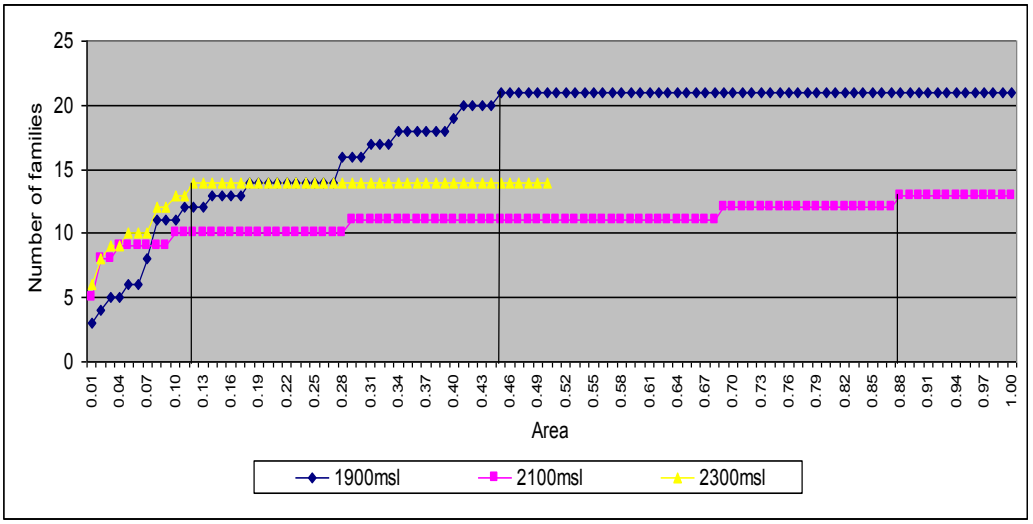

Fig: 8 Relationship between altitudinal gradient with respect to the families (Tree species)

Note: Class A (30.1-60.0), Class B (60.1-90.0), Class C (90.1-120.0) Class D (120.1-150.0), Class E (150.1-180.0), Class F (Above180.1).

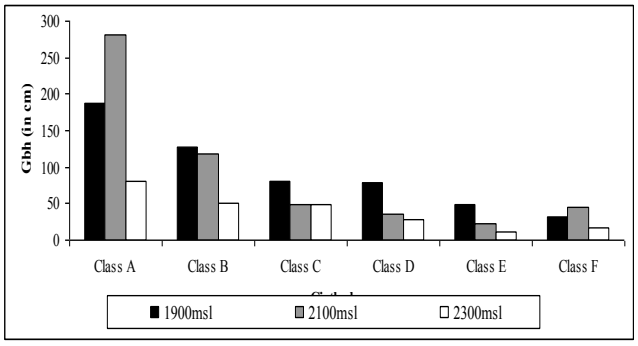

Fig: Girth class distribution pattern of mature trees with increasing altitude.

of total tree species density in three different altitudinal gradients at Mannavan shola forest of Kerala.The more number of (12 individuals) of endemic species were found in 1900 msl. The endemic species like *Rhododendron arboreum, Elaeocarpus recurvatus , Meliosma simplifolia and Mahonia leschnaultii* are distributed only in 2300 msl , while the species like *Cinnamomum sulphuratum, Litsea wightiana, Syzygium densiflorum and Neolitsea scrobiculata* are common in all elevation gradients. *Ilex wightiana,Cinnamomum sulphuratum, Litsea wigthiana, Syzygium densiflorum and Neolitsea scrobiculata* are common in 2100 and 2300 msl respectively. Most of the species had narrow range of distribution. This may due to variation in ecophysiological conditions of different altitudinal ranges, which favours different species composition (Chawla *et al*., 2008).

Discussion and Conclusion

The shola forest was analysed by establishing permanent sample plots (two 1 ha and 0.5 ha at three different altitudinal gradients such as 1900, 2100 and 2300 msl respectively).The analysis of tree species diversity results, a total of 40 species ha^{-1}, 34 genera and 21 families in 1900 msl, followed by 31 species ha^{-1}, 21genera and 15 families in 2100 msl and24 species $ha^{-0.5}$, 21genera and 13 families in 2300 msl respectively. The altitude increases as the distribution of species decreases.

The shola forests are of unique ecosystem that harbours many tree species, which are endemic to the Western Ghats of peninsular India. From the study are about 20 % of listed tree species were endemic to the Western Ghats. The plant diversity of shola forests were evaluated by laying out permanent sample plots in Shola forests of Kerala (Chandrashekara *et al*., 1998) and rich species diversity when compared to other forest types of Kerala (Chandrashekara and Jayaraman, 2002). The

Table: 3 List of endemic plant taxa from Mannavan Shola Forest (Anamudi Shola National Park) of Kerala.

SI No.	Name of species	Family	1900 msl	2100msl	2300msl
1	*Actinodaphne bourdillonii*	Lauraceae	√		
2	*Ardisia rhomboidea*	Myrsinaceae	√	√	
3	*Beilschmiedia wightii*	Lauraceae	√	√	
4	*Cinnamomum sulphuratum*	Lauraceae	√	√	√
5	*Elaeocarpus recurvatus*	Elaocarpaceae			√
6	*Glochidion neilgherrense*	Euphorbiaceae	√		
7	*Ilex wightiana*	Aquifoliaceae		√	√
8	*Gomphandra coriacea*	Icacinaceae	√	√	
9	*Lasianthus acuminatus*	Rubiaceae	√	√	
10	*Ligustrum perrottettii*	Oleaceae			√
11	*Litsea floribunda*	Lauraceae	√		
12	*Litsea wightiana*	Lauraceae	√	√	√
13	*Mahonia leschnaultii*	Berberidaceae			√
14	*Meliosma simplifolia*	Meliosmaceae			√
15	*Neolitsea scrobiculata*	Lauraceae	√	√	√
16	*Rhododendron arboreum*	Ericaceae			√
17	*Syzygium densiflorum*	Myrtaceae	√	√	√
18	*Ternstromemia japonica*	Theaceae	√		
19	*Vaccinium leschnaultii*	Vacciniaceae			√

floristic, structural and edaphic attributes of the grassland-shola forests of Eravikulam in Peninsular India by Jose *et al* (1994). Hence, the present study highlights the floristic diversity of Mannavan Shola forest in Anamudi Shola National Park in the Southern Western Ghats, Kerala.

The altitudinal gradient is one of ecological factor, which can influence the rate of distribution of tree species in tropical montane evergreen forests. In addition to this, some of the factors like size of the forest cover, climate conditions, pattern of temperature, short period of growing season and other ecological factors may also affect the distribution of species at different altitudinal gradients. Various anthropogenic activities like road construction, Tourism, over-exploitation of medicinal plants posing a threat to the fragile ecosystem of the shola forests. The present study will be helpful in formulating strategies for proper conservation of the floristic diversity of the Mannavan Shola forest in Anamudi Shola National Park in Southern Western Ghats of Kerala.

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