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Assessing vulnerability and climate change impact on the vegetation structure and composition in wet evergreen and shola forests of Kerala part of the Western Ghats

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ABSTRACT OF PROJECT PROPOSAL

Code	KFRI 380/02
Title	Assessing vulnerability and climate change impact on the vegetation structure and composition in wet evergreen and shola forests of Kerala part of the Western Ghats
Objectives	To assess vulnerability and climate change impacts on the vegetation structure and composition in three forest types namely the low elevation evergreen forests, mid elevation evergreen forests and shola forests.
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Contents

Executive summary

The Western Ghats located in the Indian sub-continent, is one of the biologically and bio-geographically richest hill ranges in the world and is considered as a mega-centre of biodiversity. Like in other regions of the world, here also it is predicted that the global climate change, particularly in the form of increasing atmospheric temperature and rainfall, and rising sea level, would alter the forest structure and floristic composition. In the present study, attempts were made to predict the possible impact of climate change in three forest types, namely, the low elevation evergreen forests, mid elevation evergreen forests and shola forests. For each forest type, plots were selected along the altitudinal gradients and comparative analyses were made for species diversity and phytosociological features.

A comparative study was carried out in a swamp forest (altitude 76 m above mean sea level) and in a forest patch located at an altitude 372 m above mean sea level. In both the plots, tree species such as, *Knema attenuata*, *Myristica dactyloides* and *Polyalthia fragrans* are dominant. However, contribution by these species to the total Importance Value Index (IVI) is relatively less in the higher altitude forest patch. In addition, these species show certain morphological features such as, stilt roots and breathing roots only when they are growing in the swampy areas. In higher altitude forest patch, comparatively high species diversity is recorded and this can be attributed to two factors, namely, the low dominance of Myristicaceous species and partitioning of resources by species characteristic to a wide range of elevation. It is clear from this study that the Myristica swamps represent a distinct plant association in lowlands of Kerala. The climate change in India, which is expected to increase the water table in the low-lying areas, may not directly alter habitats and the vegetation structure and composition in myristica swamps located here. However, the loss of coastal land due to inundation and intrusion of salinity as a consequence of climate change may lead to the encroachment of Myristica swamps and their conversion for agriculture, construction, industrial uses etc.,

Possible impact of climate change in mid elevation forests and high elevation forests (shola forests) is in the form of increase in atmospheric temperature and rainfall. It is also expected that the temperature in a forest patch located at a given altitude could rise to the level of temperature being experienced in the lower altitude forests. In this context, in a given forest type, comparison of vegetation structure and composition of forest patches located in the relatively higher altitude with those in the lower altitude was made, to provide an indication of possible species composition and other phytosociological features in the higher altitude forest patches. Study indicated that in the relatively undisturbed forest patches, located in an altitudinal gradient which were selected to represent the medium elevation evergreen forest type, *Palaquium ellipticum*, *Mesua ferrea* and *Cullenia exarillata* remained as the dominant tree species. Thus,

climate change may not alter the vegetation to an extent where the vegetation alters drastically. However, number of species, density and values obtained for species diversity index, both in tree and seedling communities are more in high altitude forests. Therefore, possible impact of climate change on relatively high altitude forests could be the reduction in species diversity and density of tree and seedling communities. A clear increasing trend in density, basal area and contribution to the total species importance index values by *Mesua ferrea* and the family Lauraceae with increase in elevation was noticed. Thus, it is also possible to predict that due to climate change, in higher elevation forest patches, current dominance of *Mesua ferrea* and Lauraceae may be reduced.

Shola forest patches along the altitudinal gradient are different from each other in terms of dominant species in their tree communities. In this forest type, as the elevation increases, the dominance of *Cinnamomum perrottetii* and *Microtropis ramiflora* increased respectively in tree and seedling communities. In addition, the species composition in higher altitude forests are significantly different from the plots located in lower elevation shola forests as indicated by the similarity index values obtained for tree and seedling communities. Thus it can be predicted that, due to climate change, in the higher altitude shola forests, the dominance of *Cinnamomum perrottetii and Microtropis ramiflora* may be reduced and species composition may be changed into that being seen in lower altitude sholas. Currently, in higher altitude shola forest patches, density of tree and seedlings are more than those in lower altitude shola forest patches. Even the height of the trees is also relatively less. Thus, it can also be predicted that due to climate change, density of trees and seedling and height of the trees could increase in the higher elevation sholas.

In some studies related to forest disturbance and regeneration, it is hypothesized that the impact of climate change on forest microclimate and vegetation structure and composition would be similar to that of disturbance in the forest. Thus it is also mentioned that the studies on floristic diversity, vegetation structure, composition and regeneration patterns in the disturbed forests in a given forest type would help to predict the impact of climate change on these parameters. In this context, in the present study, in each forest type, a disturbed forest and a relatively undisturbed forest patch located in an almost identical altitude, were compared for their vegetation structure and composition with special reference to tree communities. Study indicated that in each of the three forest types, disturbed and undisturbed forest patches are similar in terms of the occurrence of same set of dominant species of the given forest type. However, in each of the three forest types, unlike in the undisturbed forest patch, in the disturbed forest patch a set of deciduous or light demanding tree species contributed considerably to the total IVI of tree community. A significant difference in terms of species composition is also observed between undisturbed forest and disturbed forest situated in a given altitude when they were independently compared with the undisturbed forest situated in a relatively lower altitude. Based on all these observations, it is possible to conclude that in the relatively undisturbed forest patch located at higher altitude in a given forest type, the climate change probably offer competitive advantages over the other species for some species typical to the relatively undisturbed forests. On the other hand, human disturbance alters the vegetation structure and composition of tree community in such a way that light demanding or deciduous tree species, which are generally absent or poorly represented in a relatively undisturbed forests, become dominant. Thus it is suggested that monitoring and detection of vegetation responses to climate changes should be done by carefully selecting the plots which do not show any sign of other kinds of disturbance.

1. Introduction

Global climatic change is a normal process on a geological time scale. However, increasing emission of greenhouse gases like carbon dioxide, which trap heat, are causing global temperature to rise. This process called global warming, triggers off a series of climatic changes, resulting in extreme events such as droughts, floods and cyclones. According to Hulme and Viner (1998), the southern peninsular India would experience a relatively moderate increase of 2.0-2.5 ^{0}C in winter, 3.0-3.5 ^{0}C during early summer and 0.5-1.0 ^{0}C during the summer monsoon season. It is also projected that in this part of India, rainfall in Southwest Monsoon will generally increase by about 10-30% while the Northeast Monsoon will increase by 50-70%. In addition, the dry season length is also generally expected to increase, whereas soil moisture is projected to increase by 15-25%. It is also predicted that by the year 2100, atmospheric temperature in India may be 1.4 to 5.8 ^{O}C higher than the present day temperature. Similarly, the sea level may be 9 to 88 cm higher than the present level (IPCC, 2001; Shukla *et al.*, 2002). Attempts have been made to understand the impact of climate change on climate-sensitive systems such as agriculture (Mitra, 1992; Sinha,1997), forestry (Sukumar *et al.*, 1995; Achanta and Kanetkar, 1996; Deshingkar *et al.*, 1997) and some other natural resources (Asthana, 1993; Bhatt and Sharma,2002).

It may be pointed out here that within the tropical region, the primary difference in temperature is related to elevation, with an average mean annual temperature reduction of 5-6 ^{0}C per 1,000 m increase in elevation (NRC, 1982). According to Pascal (1988), in the Western Ghats of India, the major gradient in temperature is linked to altitude and the annual mean temperature reduction of 0.8 to 0.9 ^{0}C per 100 m increase in elevation could be seen. Thus, for analysing the potential impact of climate change on vegetation structure and composition, studies on vegetation along the transect are useful. This is because the current climatic conditions in the relatively higher altitude locations are expected to alter in future in such a way that this area would experience the climatic conditions of the present low elevation locations. Thus, due to climatic change, the present day vegetation structure and composition in the lower elevation localities would be seen in future in higher elevation localities. With this background in mind, several studies have been carried out to predict the future vegetation structure, composition or response of different organisms for the possible climatic changes. For instance, Ravindranath and Sukumar (1998) predicted the change of forest type boundaries along altitudinal and rainfall gradient, with species migrating from lower to higher altitudes and the drier forest types being transformed to moister types. Considering the usefulness to predict the impact of climate change on the vegetation structure and composition in different types of forests, the present study was conducted in the lowland and midland evergreen forests and shola forests in the Kerala part of the Western Ghats in India. The overall objective of the study was to assess vulnerability and climate change impacts on the vegetation structure and composition with special reference to tree communities in shola and evergreen forests of Kerala.

2. Study areas and Methods

2.1 Study areas and climate

The Kerala part of the Western Ghats covers an area of 7720 km^2 under forests with 45.6% of the forest area under evergreen, semi-evergreen and shola forest types. While the moist deciduous forests cover about 53.11% of total forest area in the State, the remaining 1.3% are represented by dry deciduous forest type (Nair, 1997). Pascal (1998) broadly categorized the evergreen forests into three groups, namely, a) Plains and low elevation types, b) Medium elevation types, and c) High altitude types. While the evergreen types of the plains and low elevations are confined to a narrow belt from the foot of the Ghats up to 800 m amsl, medium elevation evergreen forests represent those evergreen forests at 800 m to 1750 m amsl. Shola forests, which are seen between 1800 and 2700 m amsl, represent high altitude forests (Blasco, 1971; Nair *et al.*, 2001). However, in a given west-east gradient, relatively undisturbed forest plots are not available in all altitudinal gradients. Thus in the present study, the vegetation structure and composition in three evergreen forest types (low elevation type, medium elevation type and high altitude type) were analysed separately. In each forest type, forest plots at different altitudinal gradients were selected. Details of the plots are given in Table 1.

Since the forest plots in a given forest type are located within 10 km radius and no reliable weather stations are present near each plot, weather data were collected for each forest type from nearby reliable weather station.

In the low elevation evergreen forests, mean annual rainfall recorded is 2600 mm with maximum rainfall in July (1000 mm) and minimum in March (25 mm). Annual mean maximum temperature is 37.3 ^{0}C and the annual mean minimum temperature is 17.0 ^{0}C. May is the hottest month with mean maximum temperature of 34.6 ^{0}C and January the coolest with mean maximum temperature of 18.6 ^{0}C. Soil is red lateritic, and acidic (pH 5.8 to 6.6) with high organic content.

In medium elevation evergreen forests, mean annual rainfall is 2830 mm, most of which (78%) falls during June to September. The mean monthly maximum temperature during the monsoon is 23.8 ^{0}C and the mean minimum is 20.5 ^{0}C. During the dry season, the mean maximum is 25.2 ^{0}C and minimum is 20.4 ^{0}C. The soil is red, sandy loam, porous and of lateritic origin (Oxysol). The pH ranges from 4.8-5.1.

Table.1. Study sites in evergreen and shola forests in Kerala

Location	Altitude (m above mean sea level)	Longitude	Latitude	Status
Plains and low elevation evergreen forests				
Sivapuram	76	75.6161	11.9197	Undisturbed
Kavadikkanam	335	75.2671	12.5319	Disturbed
Kannavam	372	75.7764	11.8409	Undisturbed
Medium elevation evergreen forests				
Pothumala-1	810	76.6614	10.4328	Undisturbed
Pothumala-2	1090	76.6636	10.4368	Undisturbed
Pothumala-3	1250	76.6551	10.4442	Undisturbed
Pothumala-4	1350	76.6512	10.4402	Selectively logged
Pothumala-5	1475	76.6602	10.4501	Undisturbed
Shola forests				
Aruvikkad	1910	77.0934	10.1615	Disturbed
Vagadurai	1926	77.0953	10.1862	Undisturbed
Rajamalai	2191	77.0214	10.1118	Undisturbed
Umayamalai	2412	77.0512	10.1124	Undisturbed

In shola forest area, annual rainfall recorded is 4040 mm (Kallarackal and Somen, 1999) with maximum rainfall in July (1683 mm) and minimum in March (3 mm). Annual mean maximum temperature is 27.7 ^{0}C and the annual mean minimum temperature is 11.0 ^{0}C. During monsoon (June-September), mean temperature is 16.3 ^{0}C while it is 17.54 ^{0}C during the dry season (Oct-May). May is the hottest with mean maximum temperature of 24.1 ^{0}C and January is the coldest with mean maximum temperature of 15.3 ^{0}C. Relative humidity varies from 65-82%. Soil is loamy and acidic with high organic content. The pH varies from 5.2-5.6.

2.2 Vegetation analysis

In each of the above mentioned locations, three forest plots, each of 0.5 ha in size, were marked. The size of the plot was determined based on drawing the species-area curve. In most of the forest sites, the species-area curve became smooth much before the size of the plot was 3500 m^2 to 4500 m^2. However for uniform sized plots, in each forest site, a 0.5 ha plot was marked and which in turn was divided into 50 quadrats 10 m x 10 m in size. In each quadrat, all the trees above 10.1 cm girth at breast height (gbh; 1.37 m from the ground) were first identified and gbh of each tree was recorded. For the trees with large buttresses, girth was measured just above the level of buttress. In each plot, 12 sub-quadrats of 5 m x 5 m, each one in a 10 m x 10 m were marked for enumerating tree seedlings. Since duration of the project was short, phytosociological analysis was not done for shrub and herb communities. However, a checklist of herbs and shrub species in each forest plot was prepared.

The total number of stems per ha was estimated separately for trees and tree seedlings. Basal area of all trees and tree seedlings was also calculated. Formulae used for calculating the relative density, relative frequency and relative dominance are given below:

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

$$\text{Frequency} = \frac{\text{number of quadrats in which a species found x 100}}{\text{number of quadrats studied}}$$

$$\text{Relative frequency (RF)} = \frac{\text{frequency of a given species x 100}}{\text{sum of frequency of all species}}$$

$$\text{Relative dominance (R Dom)} = \frac{\text{total basal area of a given species x100}}{\text{total basal area of all species}}$$

Importance value index (IVI) of a given species was calculated as the sum of its relative density, relative dominance and relative frequency. Species with highest value for IVI among a set of species in the community can be considered as the most dominant one. In this method, in a forest plot, a set of dominant species was identified. The dominance of a set of species in a given forest patch is an indication of the fact that they are adapted to the given habitat. Furthermore changes in the microclimatic conditions in the habitat could alter the distribution pattern, density and growth of species prevailing in the given habitat. In addition, difference in the climatic and other factors in two nearby plots could be responsible for the difference in the importance value of species common in both plots. Thus, for comparing plots in a given forest type but in different altitudes, importance values obtained for trees and tree seedlings of species common to both plots were considered as one of the parameters.

Shannon-Wiener index (Shannon and Weaver, 1963) was calculated using the following formula to measure relative abundance:

$$\text{Species diversity index (H)} = -\sum\left[\left(\frac{n_i}{N}\right)\log_2\left(\frac{n_i}{N}\right)\right]$$

Where H= Shannon-Wiener index calculated to the base 2 of species diversity; n_i = number of individuals of species I; N= total number of individuals of all species in the community.

The index of dominance of the community was calculated by Simpson's index (Simpson, 1949) as:

$$C = \sum \left(\frac{n_i}{N} \right)^2$$

where C= Simpson's index of dominance; n_i = number of individuals of species I; N= total number of individuals of all species in the community.

Sorensons' Similarity index (Kershaw, 1973) was calculated for comparing the vegetation in different altitudes of a given forest type.

Similarity index = 2C/A+B

Where, C= Total number of common species of two forest patches, A= total number of species in forest patch A, and B= total number of species in forest patch B.

3. Results

3.1 Lower elevation forests

A comparative analysis made in the relatively undisturbed forests located at Sivapuram (76 m amsl) and at Kannavam (372 m amsl) indicated that the tree community in the forest at Sivapuram was dominated by species like *Knema attenuata*, *Myristica dactyloides*, *Holigarna arnottiana*, *Polyalthia fragrans* and *Hopea parviflora* (Table 2). On the other hand, in Kannavam forest *Knema attenuata*, *Myristica malabarica*, *Holigarna grahamii*, *Cinnamomum malabatrum* and *Polyalthia fragrans* dominated the tree community. The study indicated that only 17 tree species were common to both forests and thus similarity index value of 0.4 was recorded. Comparison of the total contribution by these 17 species to the total IVI indicated that the value was more in Sivapuram forest than in Kannavam forest. However, the contribution by individual species may be significantly less in Kannavam forest as in the case of Knema attenuata and Myristica dactyloides. The study also showed that the total number of species, density and basal area of tree (gbh > 10.1 cm) were significantly (P>0.05) higher in the higher elevation plot (Kannavam plot) (Table 3). In these two plots, totally 68 tree species belonging to 30 families were recorded with Myristicaceae, Anacardiaceae, Annonaceae, Lauraceae and Euphorbiaceae as dominant families. For instance, the contribution to total IVI by the species belonging to these five families is 67% and 55% in Sivapuram and Kannavam plots respectively. However, the contribution by the family Myristicaceae is less in Kannavam plot (18% to the total SIVI in the tree community) than in Sivapuram plot (48% to the total SIVI in the tree community).

Table 2. Mean Importance Value Index of trees (gbh ≥ 10.1 cm) in forest plots at Sivapuram (76 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitudes (in m above msl)	
		76m	372 m
Species common to both plots			
Aglaia elaeagnoidea	Meliaceae	7.07	5.04
Alstonia scholaris	Apocyanceae	10.62	4.43
Artocarpus hirsutus	Moraceae	10.56	4.95
Cinnamomum malabatrum	Lauraceae	4.67	19.02
Diospyros bourdillonii	Ebenaceae	9.65	4.16
Ficus nervosa	Moraceae	2.64	5.61
Diospyros bourdillonii	Ebenaceae	9.65	4.16
Holigarna arnottiana	Anacardiaceae	34.67	1.12
Hydnocarpus pentandra	Flacourtiaceae	7.46	2.13
Ixora brachiata	Rubiaceae	5.05	1.16
Knema attenuata	Myristicaceae	80.76	31.85
Mallotus philippensis	Euphorbiaceae	0.79	1.18
Mangifera indica	Anacardiaceae	1.15	2.36
Mastixia arborea	Cornaceae	2.49	0.60
Polyalthia fragrans	Annonaceae	12.55	18.72
Sterculia guttata	Sterculiaceae	0.81	1.98
Symplocos racemosa	Symplocaceae	4.20	6.66
Vitex altissima	Verbenaceae	0.88	0.83
Species recorded in one plot			
Actinodaphne hookeriana	Lauraceae	1.72	0
Diospyros oocarpa	Ebenaceae	2.26	0
Elaeocarpus tuberculatus	Elaeocarpaceae	8.60	0
Hopea parviflora	Dipterocarpaceae	12.28	0
Lophopetalum wightianum	Celastraceae	0.77	0
Myristica dactyloides	Myristicaceae	62.80	0
Persea macrantha	Lauraceae	1.32	0
Prunus zeylanica	Rosaceae	3.24	0
Pterospermum reticulatum	Sterculiaceae	1.02	0
Syzygium sp.	Myrtaceae	5.69	0
Strombosia zeylanica	Olacaceae	4.30	0
Alseodaphne semecarpifolia	Lauraceae	0	1.05
Antiaris toxicaria	Moraceae	0	4.27
Artocarpus heterophyllus	Moraceae	0	0.86
Baccaurea courtallensis	Euphorbiaceae	0	7.40
Bischofia javanica	Euphorbiaceae	0	4.31
Caryota urens	Arecaceae	0	2.57
Chionanthus malabarica	Oleaceae	0	1.07
Croton malabaricus	Euphorbiaceae	0	2.18
Cryptocarya bourdillonii	Lauraceae	0	0.53

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Table 2 (cont'd). Mean Importance Value Index of trees (gbh ≥ 10.1cm) in forest plots at Sivapuram (76 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitudes (in m above msl)	
		76m	372 m
Diospyros candolleana	Ebenaceae	0	1.08
Diospyros paniculata	Ebenaceae	0	5.58
Diospyros sp.1	Ebenaceae	0	3.39
Drypetes elata	Euphorbiaceae	0	3.92
Dysoxylum malabaricum	Meliaceae	0	1.78
Filicium decipiens	Sapindaceae	0	14.64
Flacourtia montana	Flacourtiaceae	0	1.80
Garcinia gummi-gutta	Clusiaceae	0	0.52
Garcinia morella	Clusiaceae	0	0.52
Harpullia arborea	Sapindaceae	0	1.50
Holigarna grahamii	Anacardiaceae	0	27.29
Holigarna sp.2	Anacardiaceae	0	8.15
Lagerstroemia lanceolata	Lythraceae	0	5.25
Litsea floribunda	Lauraceae	0	0.76
Litsea laevigata	Lauraceae	0	0.94
Meiogyne ramarowii	Annonaceae	0	4.23
Myristica malabarica	Myristicaceae	0	21.73
Nothopegia sp.	Anacardiaceae	0	0.52
Otonephelium stipulaceum	Sapindaceae	0	2.14
Palaquium ellipticum	Sapotaceae	0	1.47
Polyalthia coffeoides	Annonaceae	0	8.43
Pterospermum rubiginosum	Sterculiaceae	0	0.59
Sapindus laurifolia	Sapindaceae	0	6.49
Stereospermum sp.	Bignoniaceae	0	2.56
Syzygium munronii	Myrtaceae	0	1.09
Tabernaemontana heyneana	Apocyanceae	0	2.12
Toona ciliata	Meliaceae	0	1.60
Trichilia connaroides	Meliaceae	0	11.88
Vepris bilocularis	Rutaceae	0	6.44
Xanthophyllum flavescens	Xanthophyllaceae	0	3.86
Unidentified		0	11.71

Table 3. Basic information on the tree communities in forests at Sivapuram (76 m above msl) and Kannavam (372 m above msl). N= 3 replicate plots at each location.

Parameters	Tree categories			
	Trees		Tree Seedlings	
	Plots at different altitudes (in m above msl)		Plots at different altitudes (in m above msl)	
	76 m	372 m	76 m	372 m
Number of species	28	57	14	26
Density (number of individuals ha^{-1})	806±12	884± 9	2467±148	4033± 168
Basal Area (m^2 ha^{-1})	34.3±3.8	46.9± 2.4	0.60±0.09	1.00±0.02
Species Diversity Index value (H)	3.12± 0.42	4.87± 0.32	3.25±0.04	3.80±0.21
Species Dominance Index value (C)	0.201± 0.022	0.057± 0.011	0.144±0.02	0.116±0.005

In Sivapuram forest plot, 14 tree species were seen in the seedling phase with the dominance of species such as *Myristica dactyloides*, *Knema attenuata*, *Symplocos racemosa*, *Antidesma zeylanica* and *Diospyros oocarpa* (Table 4). *Aglaia elaeagnoidea*, *Knema attenuata*, *Myristica malabarica*, *Antidesma zeylanica* and *Drypetes elata* were the most dominant species among 25 species recorded in the seedling phase in Kannavam forest. Only six species were common to both plots and thus the similarity index value was only 0.36. Species belonging to families like Lauraceae, Clusiaceae and Meliaceae were absent in Sivapuram forest while they contributed about 40% of the total IVI of the seedling community in Kannavam forest. Contribution by Myristicaceous species to the total IVI is significantly more in Sivapuram forest (42%) than in Kannavam forest (22.8%).

Table 4. Mean Importance Value Index (IVI) of tree seedlings (gbh ≤ 10.0cm) in forest plots at Sivapuram (76 m amsl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitudes (in m above msl)	
		76 m	372 m
Species recorded in both plots			
Antidesma zeylanica	Euphorbiaceae	22.30	27.35
Artocarpus hirsutus	Moraceae	6.10	2.56
Aglaia elaeagnoidea	Meliaceae	0	65.11
Holigarna arnottiana	Anacardiaceae	14.79	2.94
Hydnocarpus pentandra	Flocourtiaceae	6.58	5.23
Knema attenuata	Myristicaceae	36.67	39.34
Polyalthia fragrans	Annonaceae	8.25	7.43

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Table 4 (cont'd). Mean Importance index values of tree seedlings (gbh ≤ 10.0cm) in forest plots at Sivapuram (76 m amsl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitude (in m above msl)	
		76 m	372 m
Species recorded in one plot			
Aporusa lindleyana	Euphorbiaceae	14.12	0
Diospyros oocarpa	Ebenaceae	18.85	0
Elaeocarpus tuberculatus	Elaeocarpaceae	10.24	0
Hopea parviflora	Dipterocarpaceae	11.62	0
Hopea parviflora	Dipterocarpaceae	11.62	0
Myristica dactyloides	Myristicaceae	90.36	0
Olea dioica	Oleaceae	21.58	0
Symplocos racemosa	Symplocaceae	31.45	0
Vitex altissima	Verbenaceae	7.08	0
Alseodaphne semecarpifolia	Lauraceae	0	6.29
Antiaris toxicaria	Moraceae	0	3.70
Baccaurea courtallensis	Euphorbiaceae	0	8.71
Cinnamomum malabatrum	Lauraceae	0	12.40
Diospyros bourdillonii	Ebenaceae	0	7.67
Diospyros paniculata	Ebenaceae	0	5.05
Drypetes elata	Euphorbiaceae	0	15.63
Dysoxylum malabaricum	Meliaceae	0	4.55
Garcinia gummi-gutta	Clusiaceae	0	12.43
Garcinia talbotii	Clusiaceae	0	3.83
Myristica malabarica	Myristicaceae	0	28.95
Palaquium ellipticum	Sapotaceae	0	6.93
Syzygium gardneri	Myrtaceae	0	3.23
Syzygium munronii	Myrtaceae	0	3.23
Trichilia connaroides	Meliaceae	0	14.68
Zanthoxylum rhetsa	Rutaceae	0	2.35
Unidentified		0	7.57

A comparative study of the vegetation structure and composition with special reference to tree community was conducted in a relatively undisturbed forest (Kannavam) and a disturbed forest (Kavadikkanam), situated almost at an identical altitude. The Kavadikkanam plot shows several signs of disturbances such as coppicing shoots, harvested poles, pruned trees etc. Similarity index value obtained for Kavadikkanam forest and Kannavam forest is 0.5 with 23 species seen in Kavadikkanam were absent in Kannavam. These 23 species contributed to 50% of the species importance value calculated for tree community. In addition, it was also observed that in the Kavadikkanam forest plot, contribution by the light demanding species and those characteristic to moist deciduous forests such as, *Xylia xylocarpa*, *Pterospermum reticulatum*, *Macaranga peltata* and *Terminalia paniculata* to the total IVI was 33% (Table 5). Even though the tree density was relatively more, species diversity and basal area were less in Kavadikkanam than in Kannavam (Table 6). The seedling community in Kavadikkanam was dominated by *Knema attenuata*, *Ixora brachiata*, *Litsea* sp., *Aglaia elaeagnoidea*, and *Syzygium cumini* with only three species (*Aglaia elaeagnoidea*, *Diospyros bourdillonii* and *Knema attenuata*) were common in Kavadikkanam and Kannavam plot (Table 7). In Kavadikkanam plot, number of tree species, density, basal area and species diversity of tree seedling community were comparatively less than those recorded in Kannavam forest (Table 6).

Table 5. Mean Importance Value Index of tree (gbh ≥ 10.1cm) in forest plots at Kavadikkanam (at 335 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitude (in m above msl)	
		335 m	372 m
Species common to both plots			
Aglaia elaeagnoidea	Meliaceae	5.45	5.04
Alseodaphne semecarpifolia	Lauraceae	1.70	1.05
Alstonia scholaris	Apocynaceae	6.91	4.43
Antiaris toxicaria	Moraceae	2.15	4.27
Baccaurea courtallensis	Euphorbiaceae	1.79	7.40
Diospyros bourdillonii	Ebenaceae	1.88	4.16
Diospyros sp.	Ebenaceae	10.38	3.39
Drypetes elata	Euphorbiaceae	1.82	3.92
Flacourtia montana	Flocourtiaceae	0.56	1.80
Garcinia morella	Clusiaceae	0.63	0.52
Holigarna arnottiana	Anacardiaceae	5.88	1.12
Hydnocarpus pentandra	Flocourtiaceae	0.53	2.13
Ixora brachiata	Rubiaceae	14.57	1.16
Knema attenuata	Myristicaceae	70.23	31.85
Lagerstroemia lanceolata	Lythraceae	3.88	5.25
Litsea laevigata	Lauraceae	0.95	0.94
Mallotus philippensis	Euphorbiaceae	8.38	1.18
Mangifera indica	Anacardiaceae	1.13	2.36
Meiogyne ramarowii	Annonaceae	1.08	4.23
Myristica malabarica	Myristicaceae	1.51	21.73
Sapindus laurifolia	Sapindaceae	3.28	6.49
Sterculia guttata	Sterculiaceae	0.59	1.98
Symplocos racemosa	Symplocaceae	1.27	6.66
Tabernaemontana heyneana	Apocynaceae	0.55	2.12
Vitex altissima	Verbenaceae	0.53	0.83
Xanthophyllum flavescens	Xanthophyllaceae	0.64	3.86
Unidentified		10.50	11.71
Species recorded in one plot			
Actinodaphne anguistifolia	Lauraceae	1.35	0
Antidesma menasu	Euphorbiaceae	1.69	0
Aporusa bourdillonii	Euphorbiaceae	4.27	0

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Table 5 (cont'd). Importance Value Index of tree (gbh ≥ 10.1cm) in forest plots at Kavadikkanam (at 335 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitude (in m above msl)	
		335 m	372 m
Diospyros oocarpa	Ebenaceae	4.68	0
Ficus exasperata	Moraceae	0.54	0
Grewia tiliifolia	Tiliaceae	0.61	0
Litsea sp.	Lauraceae	8.45	0
Macaranga peltata	Euphorbiaceae	11.24	0
Melia dubia	Meliaceae	1.13	0
Memecylon umbellatum	Melastomataceae	0.96	0
Naringi crenulata	Rutaceae	0.54	0
Melia dubia	Meliaceae	1.13	0
Memecylon umbellatum	Melastomataceae	0.96	0
Naringi crenulata	Rutaceae	0.54	0
Olea dioica	Oleaceae	19.58	0
Prunus zeylanica	Rosaceae	1.95	0
Pterospermum diversifolium	Sterculiaceae	0.53	0
Pterospermum reticulatum	Sterculiaceae	20.85	0
Syzygium cumini	Myrtaceae	8.17	0
Syzygium sp.	Myrtaceae	7.49	0
Terminalia bellirica	Combretaceae	0.58	0
Terminalia paniculata	Combretaceae	13.14	0
Xylia xylocarpa	Fabaceae	31.51	0
Artocarpus heterophyllus	Moraceae	0	0.86
Artocarpus hirsutus	Moraceae	0	4.95
Bischofia javanica	Euphorbiaceae	0	4.31
Croton malabaricus	Euphorbiaceae	0	2.18
Cryptocarya bourdillonii	Lauraceae	0	0.53
Diospyros candolleana	Ebenaceae	0	1.08
Diospyros paniculata	Ebenaceae	0	5.58
Dysoxylum malabaricum	Meliaceae	0	1.78
Ficus nervosa	Moraceae	0	5.61
Filicium decipiens	Sapindaceae	0	14.64
Garcinia gummi-gutta	Clusiaceae	0	0.52
Harpullia arborea	Sapindaceae	0	1.50
Holigarna grahamii	Anacardiaceae	0	27.29
Holigarna sp.	Anacardiaceae	0	8.15
Litsea floribunda	Lauraceae	0	0.76
Mastixia arborea	Cornaceae	0	0.60
Nothopegia sp.	Anacardiaceae	0	0.52
Otonephelium stipulaceum	Sapindaceae	0	2.14
Palaquium ellipticum	Sapotaceae	0	1.47
Polyalthia coffeoides	Annonaceae	0	8.43

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Table 5 (cont'd). Importance Value Index of tree (gbh ≥ 10.1cm) in forest plots at Kavadikkanam (at 335 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitude (in m above msl)	
		335 m	372 m
Polyalthia fragrans	Annonaceae	0	18.72
Pterospermum rubiginosum	Sterculiaceae	0	0.59
Stereospermum sp.	Bignoniaceae	0	2.56
Syzygium munronii	Myrtaceae	0	1.09
Toona ciliata	Meliaceae	0	1.60
Trichilia connaroides	Meliaceae	0	11.88
Vepris bilocularis	Rutaceae	0	6.44

Table 6. Basic information on the tree communities in forests at Kavadikkanam (at 335 m above msl) and Kannavam (at 370 m above msl). N= 3 replicate plots at each location.

Parameters	Tree categories			
	Trees		Tree Seedlings	
	Plots at different altitude (in m above msl)		Plots at different altitude (in m above msl)	
	335 m	372 m	335 m	372 m
Number of species	52	57	15	26
Density (number of individuals ha^{-1})	1078± 19	884± 9	3400±	4033± 168
Basal Area (m^2 ha^{-1})	36.2± 1.64	46.9± 2.4	0.68±	1.00±0.02
Species Diversity Index value (H)	3.80± 0.22	4.87± 0.32	3.40±0.12	3.80±0.21
Species Dominance Index value (C)	0.1763± 0.01	0.057± 0.011	0.130±0.002	0.116±0.005

Table 7. Importance Value Index of tree seedlings (gbh ≤ 10.0cm) in forest plots at Kavadikkanam (at 335 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitude (in m above msl)	
		335 m	372 m
Species common to both plots			
Aglaia elaeagnoidea	·Meliaceae	26.01	65.11
Diospyros bourdillonii	Ebenaceae	9.75	7.67
Knema attenuata	Myristicaceae	80.91	39.34
Species recorded in one plot			
Aglaia sp.	Meliaceae	17.92	0
Diospyros oocarpa	Ebenaceae	19.84	0
Ixora brachiata	Rubiaceae	38.75	0

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Table 7 (cont'd). Mean Importance Value Index of tree seedlings (gbh ≤ 10.0cm) in forest plots at Kavadikkanam (at 335 m above msl) and Kannavam (372 m above msl)

Species	Family	Plots at different altitude (in m above msl)	
		335 m	372 m
Litsea sp.	Lauraceae	29.17	0
Meiogyne ramarowii	Annonaceae	15.19	0
Melia dubia	Meliaceae	4.70	0
Nothopegia sp.	Anacardiaceae	8.05	0
Pterospermum diversifolium	Sterculiaceae	4.57	0
Pterospermum reticulatum	Sterculiaceae	15.06	0
Syzygium cumini	Myrtaceae	20.42	0
Xylia xylocarpa	Fabaceae	6.66	0
Alseodaphne semecarpifolia	Lauraceae	0	6.29
Antiaris toxicaria	Moraceae	0	3.70
Antidesma zeylanica	Euphorbiaceae	0	27.35
Artocarpus hirsutus	Moraceae	0	2.56
Baccaurea courtallensis	Euphorbiaceae	0	8.71
Cinnamomum malabatrum	Lauraceae	0	12.40
Diospyros paniculata	Ebenaceae	0	5.05
Drypetes elata	Euphorbiaceae	0	15.63
Dysoxylum malabaricum	Meliaceae	0	4.55
Garcinia gummi-gutta	Clusiaceae	0	12.43
Garcinia talbotii	Clusiaceae	0	3.83
Holigarna arnottiana	Anacardiaceae	0	2.94
Hydnocarpus pentandra	Flocourtiaceae	0	5.23
Myristica malabarica	Myristicaceae	0	28.95
Palaquium ellipticum	Sapotaceae	0	6.93
Polyalthia fragrans	Annonaceae	0	7.43
Pterygota alata	Sterculiaceae	0	2.85
Syzygium gardneri	Myrtaceae	0	3.23
Syzygium munronii	Myrtaceae	0	3.23
Trichilia connaroides	Meliaceae	0	14.68
Zanthoxylum rhetsa	Rutaceae	0	2.35
Unidentified		0	7.57

3.2 Medium elevation evergreen forests

Palaquium ellipticum, *Mesua ferrea* and *Cullenia exarillata* were the first three dominant species in the tree community in the medium elevation forests situated in Pothumala (Table 8). These three species contributed to about 33% of the total IVI in tree community, with the contribution of *Mesua ferrea* more in the higher altitude plot. Total number of species per plot ranged from 32-38 with more number of species in the higher altitude forest patch (Table 9). Altogether 58 species were recorded from the four plots. Of these only 13 species were common to all four plots. In addition, the aggregate contribution of these 13 species the total IVI in different plots was almost same. In these forests, Lauraceae, Euphorbiaceae, Sapotaceae, Clusiaceae and Meliaceae were the dominant families. For instance, total number of species of these four families in a plot ranged from 14 to 23. Similarly the contribution by the species belonging to these families to the total IVI in the tree community was in the range from 66% to 85%. Among these dominant families, Lauraceae showed clear trend that both the number of species and the total IVI of trees belonging to it increased with increase in the altitude.

Dominant species in the tree seedling community varies from plot to plot (Table 10). For instance, in the plot located at 810 m amsl, *Palaquium ellipticum*, *Meiogyne pannosa*, *Cullenia exarillata*, *Dimocarpus longan* and *Syzygium laetum* were the first five dominant species. In the plot at 1090 m amsl, *Memecylon* sp., *Litsea floribunda, Dimocarpus longan* and *Drypetes elata* and *Litsea* sp. were dominant while in the plot at 1250 m amsl, *Heritiera papilio*, *Memecylon sp.*, *Drypetes elata, Litsea floribunda* and *Actinodaphne bourdillonii* were dominant. *Palaquium ellipticum, Mesua ferrea*, *Litsea floribunda* and *Actinodaphne bourdillonii* were dominant species in plot located at an altitude 1475 m amsl. Even in the seedling phase the contribution of species of Lauraceae increased with increase in the altitude. Number of species, density and species diversity index values both in the tree phase and seedling phase were more in the plot located at higher altitude (Table 9). However, values for the basal area were not that much different among different plots.

Table 8. Mean Importance index values of trees (gbh $\geq$ 10.1cm) in forest plots in an altitudinal gradient at Pothumala.

Species	**Family**	**Plots at different altitude (in m above msl)**			
		810 m	1090 m	1250 m	1475 m
Species recorded in all plots					
Actinodaphne malabarica	Lauraceae	2.33	8.02	1.39	11.42
Antidesma menasu	Euphorbiaceae	2.52	0.78	1.75	0.62
Cinnamomum malabatrum	Lauraceae	2.43	1.05	1.95	3.2
Cullenia exarillata	Bombacaceae	31.32	30.50	24.21	20.12
Dimocarpus longan	Sapindaceae	7.77	16.09	5.44	4.02
Diospyros sylvatica	Ebenaceae	2.02	0.49	1.04	0.26
Garcinia morella	Clusiaceae	0.69	2.30	0.87	3.56
Heritiera papilio	Lauraceae	8.71	4.83	11.61	20.12
Litsea mysorensis	Lauraceae	5.65	9.29	18.57	4.12
Mesua ferrea	Clusiaceae	27.54	21.66	21.50	45.02
Palaquium ellipticum	Sapotaceae	40.57	56.55	50.82	49.78
Polyalthia coffeoides	Annonaceae	7.65	1.41	4.91	2.36
Syzygium laetum	Myrtaceae	21.33	9.42	8.27	4.12

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Table 8 (cont'd). Importance Value Index of trees (gbh ≥ 10.1 cm) in forest plots in an altitudinal gradient at Pothumala

Species	Family	Plots at different altitude (in m above msl)			
		810 m	1090 m	1250 m	1475 m
Species recorded in three plots					
Aglaia exstipulata	Meliaceae	10.72	13.21	21.73	0
Artocarpus heterophyllus	Moraceae	2.62	4.18	7.07	0
Isonandra lanceolata	Sapotaceae	10.57	9.44	8.97	0
Myristica dactyloides	Myristicaceae	8.15	5.72	7.73	0
Agrostistachys borneensis	Euphorbiaceae	2.40	13.45	0	8.96
Drypetes wightii	Euphorbiaceae	3.52	25.72	0	4.76
Holigarna arnottiana	Anacardiaceae	7.92	0	7.81	3.26
Litsea bourdillonii	Lauraceae	8.06	0	17.32	5.68
Cassine glauca	Celastraceae	0	0.62	6.83	4.26
Drypetes elata	Euphorbiaceae	0	14.71	20.34	7.21
Litsea sp.1	Lauraceae	0	6.28	2.71	10.08
Species recorded in two plots					
Mastixia arborea	Cornaceae	3.86	0	0.69	0
Calophyllum polyanthum	Clusiaceae	0.72	0	0	1.36
Drypetes oblongifolia	Euphorbiaceae	10.93	0	0	1.20
Litsea laevigata	Lauraceae	8.01	0	0	5.16
Phoebe lanceolata	Lauraceae	0.81	0	0	5.92
Canthium sp.	Rubiaceae	0	1.19	1.23	0
Macaranga peltata	Euphorbiaceae	0	0.61	10.91	0
Syzygium sp.1	Myrtaceae	0	5.18	5.47	0
Unidentified -1		0	12.47	13.48	0
Canarium strictum	Dipterocarpaceae	0	0.77	0	2.3
Holigarna ferruginea	Anacardiaceae	0	7.64	0	3.26
Memecylon sp.	Melastomataceae	0	2.66	0	2.62
Neolitsea zeylanica	Lauraceae	0	1.76	0	17.18
Syzygium gardneri	Myrtaceae	0	0.47	0	1.26
Litsea insignis	Lauraceae	0	0	0.35	4.14
Litsea sp.3	Lauraceae	0	0	12.61	4.14
Species recorded in one plot					
Ardisia pauciflora	Myrsinaceae	8.12	0	0	0
Dysoxylum malabaricum	Meliaceae	20.43	0	0	0
Glochidion sp.	Euphorbiaceae	1.60	0	0	0
Meiogyne pannosa	Annonaceae	27.50	0	0	0
Olea dioica	Oleaceae	1.41	0	0	0
Syzygium lanceolatum	Myrtaceae	1.16	0	0	0
Tricalysia apiocarpa	Rubiaceae	1.00	0	0	0
Ficus exasperata	Moraceae	0	0.46	0	0
Unidentified-2		0	11.07	0	0
Caryota urens	Arecaceae	0	0	1.66	0

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Table 8 (cont'd). Importance Value Index of trees (gbh ≥10.cm) in forest plots in an altitudinal gradient at Pothumala

Species	Family	Plots at different altitude (in m above msl)			
		810m	1090m	1250m	1475 m
Ficus racemosa	Moraceae	0	0	0.76	0
Apollonias arnottii	Lauraceae	0	0	0	13.21
Clausena heptaphylla	Rutaceae	0	0	0	4.12
Litsea sp.2	Lauraceae	0	0	0	4.64
Persea macrantha	Lauraceae	0	0	0	2.78
Schefflera venulosa	Araliaceae	0	0	0	1.78

Table 9. Basic information on the tree communities in forest plots at Pothumala N= 3 replicate plots at each location.

Parameters	Plots at different altitude (in m above msl)			
	810 m	1090 m	1250 m	1475 m
Trees				
Number of species	33	32	33	38
Density (individuals ha^{-1})	1396± 193	1536± 68	1194±44	1742± 146
Basal area (m^2 ha^{-1})	63.61 ± 4.76	54.3±6.12	69.66±3.24	62.36± 2.46
Species Diversity Index value (H)	4.28± 0.03	4.19±0.02	4.28±0.04	4.62±0.06
Species Dominance Index value (C)	0.070± 0.01	0.071± 0	0.064± 0	0.052± 0
Tree seedlings				
Number of species	10	17	15	28
Density (individuals ha^{-1})	1960± 342	2433± 54	1800±243	2612± 43
Basal area (m^2 ha^{-1})	0.24± 0.03	0.24± 0.02	0.36± 0.02	1.48± 0.24
Species Diversity Index value (H)	2.99± 0.24	3.45±0.12	3.79±0.14	4.02±0.02
Species Dominance Index Value (C)	0.157± 0.025	0.110± 0.005	0.083± 0.004	0.071±0.005

Table 10. Importance Value Index of tree seedlings (gbh ≤ 10.0 cm) in forest plots in an altitudinal gradient at Pothumala

Species	Family	Plots at different altitude (in m above msl)			
		810 m	1090 m	1250 m	1475 m
Species recorded in all plots					
Cullenia exarillata	Bombacaceae	35.52	3.62	2.36	2.47
Dimocarpus longan	Sapindaceae	34.46	29.00	21.20	14.12
Mesua ferrea	Clusiaceae	13.92	3.49	4.49	29.29
Species recorded in three plots					
Aglaia lawii	Meliaceae	0	19.79	4.12	1.72
Drypetes elata	Euphorbiaceae	0	26.80	30.72	12.08
Heritiera papilio	Lauraceae	0	10.34	47.53	16.08
Litsea floribunda	Lauraceae	0	35.39	28.56	26.12
Litsea insignis	Lauraceae	0	10.72	21.31	7.12
Litsea sp.2	Lauraceae	0	24.64	15.99	5.16
Persea macrantha	Lauraceae	0	12.76	12.43	7.10
Species recorded in two plots					
Cinnamomum malabatrum	Lauraceae	25.01	0	0	7.12
Litsea laevigata	Lauraceae	27.80	0	0	17.08
Litsea mysorensis	Lauraceae	18.31	0	0	2.48
Syzygium laetum	Myrtaceae	31.84	0	0	4.2
Isonandra lanceolata	Sapotaceae	0	4.19	9.33	0
Mastixia arborea	Cornaceae	0	7.12	4.10	0
Actinodaphne bourdillonii	Lauraceae	0	0	30.19	24.72
Aglaia tomentosa	Meliaceae	0	0	4.10	4.7
Cassine glauca	Celastraceae	0	0	5.75	3.72
Species recorded in one plot					
Dysoxylum malabaricum	Meliaceae	3.03	0	0	0
Holigarna arnottiana	Anacardiaceae	10.50	0	0	0
Meiogyne pannosa	Annonaceae	35.60	0	0	0
Garcinia gummi-gutta	Clusiaceae	0	3.62	0	0
Apollonias arnottii	Lauraceae	0	0	0	17.16
Calophyllum polyanthum	Clusiaceae	0	0	0	5.62
Clausena heptaphylla	Rutaceae	0	0	0	2.42
Gomphandra coriacea	Icacinaceae	0	0	0	4.18
Litsea bourdillonii	Lauraceae	0	0	0	3.42
Litsea sp.1	Lauraceae	0	0	0	3.42
Litsea sp.3	Lauraceae	0	0	0	4.72
Neolitsea zeylanica	Lauraceae	0	0	0	7.02
Phoebe lanceolata	Lauraceae	0	0	0	9.12

A comparative study on the vegetation structure and composition with special reference to tree community was conducted in a relatively undisturbed forest plot and a selectively logged forest plot, situated in places with about 100 m difference in altitude. The forest patch located at 1380 m above msl was felled selectively in the year 1986 and after that forest did not experience any major disturbance. In this forest patch, *Palaquium ellipticum*, *Mesua ferrea* and *Cullenia exarillata* were dominant (Table 11). Similarity index value was 0.72 for the selectively logged plot and the relatively undisturbed plot with 25 tree species common to both plots. Further analysis indicated that in the tree community contribution of these 25 species to the total IVI was more in the selectively logged forest (84.3%) than that in the relatively undisturbed forest (77.87%). Similarly, contribution by a set of light demanding species to the total IVI of tree community was also more in selectively logged forest patch (16.5%) as against that in relatively undisturbed forest (3.2%). In the tree seedling community of selectively logged forest, *Memecylon* sp., *Litsea bourdillonii*, and *Drypetes elata* were dominant (Table 12). Similarity index value was 0.63 for the selectively logged plot and the relatively undisturbed plot with 15 tree species common in both plots. Contribution by these species to total IVI of tree seedling community was more in selectively logged forest patch (88.76%) than in the relatively undisturbed forest (60.9%). However, the contribution by light demanding species was only 3.3% in the selectively logged forest patch.

Table 11. Mean Importance Value Index of trees (gbh ≥ 10.1 cm) in forest plots in an altitudinal gradient at Pothumala

Species	Family	Plots at different altitude (m above msl)	
		1380 m	1475 m
Species recorded in both the plots			
Actinodaphne malabarica	Lauraceae	10.69	11.42
Agrostistachys borneensis	Euphorbiaceae	14.56	8.96
Antidesma menasu	Euphorbiaceae	8.95	0.62
Calophyllum polyanthum	Clusiaceae	1.20	1.36
Canarium strictum	Burseraceae	1.56	2.3
Cassine glauca	Celastraceae	6.28	4.26
Cinnamomum malabatrum	Lauraceae	7.95	3.2
Cullenia exarillata	Bombacaceae	18.21	20.12
Dimocarpus longan	Sapindaceae	9.44	4.02
Diospyros sylvatica	Ebenaceae	4.04	0.26
Drypetes elata	Euphorbiaceae	10.52	7.21
Garcinia morella	Clusiaceae	4.26	3.56
Heritiera papilio	Lauraceae	10.22	20.12
Holigarna arnottiana	Anacardiaceae	4.01	3.26
Holigarna ferruginea	Anacardiaceae	3.22	3.26
Litsea bourdillonii	Lauraceae	12.12	5.68
Litsea laevigata	Lauraceae	12.86	5.16
Memecylon sp	Melastomataceae	15.36	2.62
Mesua ferrea	Clusiaceae	32.16	45.02
Neolitsea zeylanica	Lauraceae	3.48	17.18
Palaquium ellipticum	Sapotaceae	49.89	49.78

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Table 11. Mean Importance Value Index of trees (gbh ≥ 10.1 cm) in forest plots in an altitudinal gradient at Pothumala

Species	Family	Plots at different altitude (m above msl)	
		1380 m	1475 m
Persea macrantha	Lauraceae	1.26	2.78
Polyalthia coffeoides	Annonaceae	4.91	2.36
Syzygium laetum	Myrtaceae	3.27	4.12
Species recorded in one plot			
Ardisia pauciflora	Myrsinaceae	7.21	0
Fahrenheitia zeylanica	Euphorbiaceae	3.78	0
Macaranga peltata	Euphorbiaceae	12.91	0
Maesa indica	Myrsinaceae	2.16	0
Meiogyne pannosa	Annonaceae	12.36	0
Apollonias arnottii	Lauraceae	0	13.21
Clausena heptaphylla	Rutaceae	0	4.12
Drypetes oblongifolia	Euphorbiaceae	0	1.20
Drypetes wightii	Euphorbiaceae	0	4.76
Gomphandra coriacea	Icacinaceae	0	7.12
Litsea insignis	Lauraceae	0	4.14
Litsea mysorensis	Lauraceae	0	4.12
Litsea sp.1	Lauraceae	0	10.08
Litsea sp.2	Lauraceae	0	8.78
Phoebe lanceolata	Lauraceae	0	5.92
Scheflera venulosa	Araliaceae	0	1.78
Syzygium gardneri	Myrtaceae	0	1.26

Table 12. Mean Importance Value Index of tree seedlings (gbh ≤ 10.0 cm) in forest plots in an altitudinal gradient at different at Pothumala

Species	Family	Plots at different altitude (in m above msl)	
		1380 m	1475 m
Species recorded in both the plots			
Aglaia tomentosa	Meliaceae	18.03	5.7
Cassine glauca	Celastraceae	8.96	3.72
Cullenia exarillata	Bombacaceae	8.11	2.47
Dimocarpus longan	Sapindaceae	37.2	14.12
Drypetes elata	Euphorbiaceae	28.52	12.08
Heritiera papilio	Lauraceae	14.34	16.08
Litsea bourdillonii	Lauraceae	32.75	3.42
Litsea laevigata	Lauraceae	26.67	17.08
Memecylon sp.	Melastomataceae	32.91	14.18
Mesua ferrea	Clusiaceae	14.12	29.29
Myristica dactyloides	Myristicaceae	6.33	2.1
Palaquium ellipticum	Sapotaceae	19.35	42.08

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Table 12 (cont'd). Mean Importance Value Index of tree seedlings (gbh ≤ 10.0 cm) in forest plots in an altitudinal gradient at different at Pothumala.

Species	Family	Plots at different altitude (in m above msl)	
		1380 m	1475 m
Persea macrantha	Lauraceae	11.4	7.10
Phoebe lanceolata	Lauraceae	6.1	9.12
Syzygium laetum	Myrtaceae	1.5	4.2
Species recorded in one plot			
Actinodaphne malabarica	Lauraceae	15.47	0
Fahrenheitia zeylanica	Euphorbiaceae	9.88	0
Isonandra lanceolata	Sapotaceae	7.59	0
Mastixia arborea	Cornaceae	0.77	0
Aglaia lawii	Meliaceae	0	24.72
Apollonias arnottii	Lauraceae	0	17.16
Calophyllum polyanthum	Clusiaceae	0	5.62
Cinnamomum malabatrum	Lauraceae	0	7.12
Clausena heptaphylla	Rutaceae	0	2.42
Gomphandra coriacea	Icacinaceae	0	4.18
Litsea floribunda	Lauraceae	0	26.12
Litsea insignis	Lauraceae	0	7.12
Litsea mysorensis	Lauraceae	0	2.48
Litsea sp.1	Lauraceae	0	3.42
Litsea sp.2	Lauraceae	0	5.16
Litsea sp.3	Lauraceae	0	4.72
Neolitsea zeylanica	Lauraceae	0	7.02

3.3 Shola forests

Three shola forests located at elevations 1926 m, 2191 m and 2412 m were studied for tree community composition and distribution. While *Cinnamomum perrottetii* was the first dominant species in plots located at 2191m and 2412m, *Symplocos macrophylla* was the first dominant species at (1926 m). Other dominant species include *Syzygium densiflorum*, *Neolitsea scrobiculata*, *Chionanthus linocieroides*, *Gomphandra coriacea*, *Ilex wightiana*, *Cinnamomum macrocarpum*, *Cinnamomum sulphuratum* and *Microtropis ramiflora*. However, a set of first five dominant species in different plots was different (Table 13).

Table 13. Mean Importance Value Index of tree (gbh ≥ 10.1cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)		
		1926 m	2191 m	2412 m
Species recorded in all three plots				
Actinodaphne bourdillonii	Lauraceae	1.45	7.12	10.92
Apollonias arnottii	Lauraceae	8.89	8.94	9.76
Beilschmiedia wightii	Lauraceae	5.60	7.94	8.92
Chionanthus linocieroides	Oleaceae	20.47	8.92	4.16
Cinnamomum sulphuratum	Lauraceae	2.22	16.12	14.92
Elaeocarpus recurvatus	Elaeocarpaceae	0.84	2.36	12.18
Garcinia sp.	Clusiaceae	13.75	7.94	5.92
Gomphandra coriacea	Icacinaceae	20.02	8.42	4.22
Ilex wightiana	Aquifoliaceae	17.17	24.12	28.29
Isonandra perrottetiana	Sapotaceae	2.96	7.04	9.42
Isonandra sp.	Sapotaceae	1.31	3.25	4.47
Litsea oleoides	Lauraceae	2.13	3.42	6.02
Litsea sp.	Lauraceae	3.90	2.14	10.02
Litsea wightiana	Lauraceae	6.02	7.18	5.12
Microtropis ramiflora	Celastraceae	6.92	10.92	18.12
Neolitsea scrobiculata	Lauraceae	22.19	18.36	11.08
Persea macrantha	Lauraceae	1.01	5.92	4.10
Saprosma fragrans	Rubiaceae	3.38	2.86	8.02
Symplocos macrophylla	Symplocaceae	37.75	14.02	2.2
Syzygium densiflorum	Myrtaceae	25.97	8.03	6.02
Species recorded in two plots				
Aglaia apiocarpa	Meliaceae	1.71	4.20	0
Canarium strictum	Burseraceae	2.89	3.92	0
Cinnamomum wightii	Lauraceae	13.86	10.14	0
Glochidion neilgherrence	Euphorbiaceae	17.44	6.36	0
Nothapodytes nimmoniana	Icacinaceae	3.33	4.16	0
Psychotria sp.	Rubiaceae	1.48	3.26	0
Scolopia crenata	Flacourtiaceae	3.30	3.02	0
Symplocos cochinchinensis	Symplocaceae	8.63	4.36	0
Ardisia rhomboidea	Myrsinaceae	0	3.22	7.16
Casearia coriacea	Flacourtiaceae	0	2.68	4.72
Cinnamomum macrocarpum	Lauraceae	0	16.32	14.16
Cinnamomum perrottetii	Lauraceae	0	31.24	39.88

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Table 13 (cont'd). Mean Importance Value Index of tree (gbh ≥ 10.1 cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)		
		1926 m	2191 m	2412 m
Eugenia bracteata	Myristicaceae	0	3.12	4.76
Euonymus crenulatus	Celastraceae	0	5.26	9.26
Ilex denticulata	Aquifoliaceae	0	5.92	6.72
Pittosporum tetraspermum	Pittosporaceae	0	4.98	6.08
Symplocos obtusa	Symplocaceae	0	7.98	8.30
Species recorded in one plot				
Bhesa indica	Celastraceae	1.21	0	0
Celtis tetrandra	Ulmaceae	0.99	0	0
Schefflera racemosa	Araliaceae	1.44	0	0
Syzygium sp.1	Myrtaceae	1.92	0	0
Vernonia arborea	Asteraceae	0.48	0	0
Xanthophyllum flavescens	Xanthophyllaceae	0.62	0	0
Aporusa lindleyana	Euphorbiaceae	0	3.56	0
Ligustrum perrottetii	Oleaceae	0	1.08	0
Microtropis ovalifolia	Celastraceae	0	0	12.12
Rapanea thwaitesii	Myrsinaceae	0	0	7.12

Similarity Index value obtained for plots in 1926 m and 2191 m elevation was 0.82, while that obtained for plots located at 2191 m and 2412 m was 0.83. However, the value obtained for sites located at 1926 m and 2412 m was 0.686. *Neolitsea scrobiculata* was the first dominant species in the tree seedling community in plots located at elevation 1926 m and 2191 m, while *Microtropis ramiflora* was the first dominant species in the plot located at 2412 m elevation. Other dominant species include *Apollonias arnottii*, *Syzygium densiflorum*, *Scolopia crenulata* and *Symplocos cochinchinensis* (Table 14). Similarity Index value obtained for seedling community for plots in 1926 m and 2191 m was 0.806, while that obtained for plots located at 2191 m and 2412 m was 0.912. However, the value obtained for sites located at 1926 m and 2412 m was 0.767. In these forests, species belonging to 23 families were recorded. Among these, Lauraceae, Celastraceae, Oleaceae, Aquifoliaceae, Symplocaceae and Myrtaceae contributed 70 to 74% of the total IVI of the tree and tree seedling communities. Density of tree and tree seedlings increased with the increase in altitude, however, no clear trend was recorded for parameters such as basal area, indices of species diversity and species dominance (Table 15).

Table 14. Mean Importance Value Index of tree seedlings (girth < 10.1 cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)		
		1926 m	2191 m	2412 m
Species recorded in all three plots				
Apollonias arnottii	Lauraceae	27.22	20.16	18.18
Aporusa lindleyana	Euphorbiaceae	2.31	4.68	5.72
Beilschmiedia wightii	Lauraceae	7.1	5.64	7.36
Chionanthus linocieroides	Oleaceae	5.32	7.62	6.42
Cinnamomum macrocarpum	Lauraceae	4.98	10.02	7.32
Cinnamomum wightii	Lauraceae	9.34	4.56	6.71
Eugenia bracteata	Myristicaceae	2.53	3.72	4.86
Garcinia sp.	Clusiaceae	13.14	3.46	3.18
Gomphandra coriacea	Icacinaceae	9.67	8.72	7.36
Ilex denticulata	Aquifoliaceae	3.23	4.18	5.62
Ilex wightiana	Aquifoliaceae	4.73	6.36	8.46
Isonandra perottetiana	Sapotaceae	2.53	1.36	4.12
Litsea oleoides	Lauraceae	17.02	8.94	10.18
Litsea sp.	Lauraceae	9.67	9.49	12.36
Microtropis ovalifolia	Celastraceae	9.75	8.49	13.16
Microtropis ramiflora	Celastraceae	30.53	12.56	27.08
Neolitsea scrobiculata	Lauraceae	55.34	30.08	19.76
Psychotria sp.	Rubiaceae	17.50	2.36	4.12
Saprosma fragrans	Rubiaceae	2.66	5.74	8.32
Scolopia crenata	Flacourtiaceae	15.02	24.08	18.08
Symplocos macrophylla	Symplocaceae	5.41	18.92	12.14
Symplocos cochinchinensis	Symplocaceae	10.49	23.18	15.08
Syzygium densiflorum	Myrtaceae	18.77	7.95	6.32
Species recorded in two plots				
Canarium strictum	Burseraceae	2.47	1.28	0
Nothapodytes nimmoniana	Icacinaceae	8.83	2.76	0
Actinodaphne bourdillonii	Lauraceae	0	6.74	8.91
Bhesa indica	Celastraceae	0	2.74	2.12
Cinnamomum perrottetii	Lauraceae	0	5.38	8.92
Elaeocarpus recurvatus	Elaeocarpaceae	0	3.21	5.74
Euonymus crenulatus	Celastraceae	0	10.98	6.76
Litsea wightiana	Lauraceae	0	6.12	9.12
Pittosporum tetraspermum	Pittosporaceae	0	7.86	10.12
Species recorded in one plot				
Glochidion neilgherrence	Euphorbiaceae	2.24	0	0
Ligustrum perrottetii	Oleaceae	2.53	0	0
Cinnamomum sulphuratum	Lauraceae	0	6.32	0
Isonandra sp.	Sapotaceae	0	1.78	0
Symplocos obtusa	Symplocaceae	0	6.24	7.11
Rapanea thwaitesii	Myrsinaceae	0	0	5.64
Syzygium sp.1	Myrtaceae	0	0	3.65

Table 15. Basic information on the tree communities in shola forests located in an altitudinal gradient.

Parameters	Plots at different altitude (in m above msl)		
	1926 m	2191 m	2412 m
Trees			
Number of species	39	39	31
Density (individuals ha^{-1})	1094 ± 124	1246± 49	1468±56
Basal area (m^2 ha^{-1})	52.04± 2.12	48.76± 2.48	51.36± 1.36
Species Diversity Index value (H)	3.09± 0.5	3.12± 0.12	2.89± 0.7
Species Dominance Index value (C)	0.0606± 0.004	0.0598± 0.003	0.06812± 0.002
Tree seedlings			
Number of species	27	35	33
Density (individuals ha^{-1})	4300± 340	4560±120	4940±65
Basal area (m^2 ha^{-1})	1.0±0.04	1.12± 0.03	0.98±0.02
Species Diversity Index value (H)	4.03± 0	4.36±0.007	4.30±0.003
Species Dominance Index Value (C)	0.0967± 0.003	0.0926± 0.004	0.0912± 0.003

A comparative study on the vegetation structure and composition with special reference to tree community was conducted in a relatively undisturbed and a disturbed shola forest patches, situated almost in an identical altitude. In the disturbed plot, *Clerodendrum viscosum*, *Syzygium densiflorum*, *Canthium dicoccum*, *Litsea wightianum* and *Alseodaphne semecarpifolia* were the first five dominant species in the tree phase (Table 16).

Table 16. Mean Importance Value Index of tree (gbh ≥ 10.1 cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)	
		1910 m	1926 m
Species recorded in both plots			
Actinodaphne bourdillonii	Lauraceae	9.96	1.45
Beilschmiedia wightii	Lauraceae	5.65	5.60
Canarium strictum	Burseraceae	2.99	2.89
Celtis tetrandra	Ulmaceae	1.34	0.99
Cinnamomum sulphuratum	Lauraceae	1.28	2.22
Cinnamomum wightii	Lauraceae	11.50	13.86
Elaeocarpus recurvatus	Elaeocarpaceae	1.27	0.84
Garcinia sp.	Clusiaceae	3.38	13.75
Gomphandra coriacea	Icacinaceae	18.34	20.02
Ilex wightiana	Aquifoliaceae	1.79	17.17
Isonandra perottetiana	Sapotaceae	5.68	2.96

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Table 16 (Cont'd). Mean Importance index values of tree (gbh ≥ 10.1cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)	
		1910 m	1926 m
Litsea wightiana	Lauraceae	20.31	6.02
Neolitsea fischeri	Lauraceae	0.71	0.71
Neolitsea cassia	Lauraceae	7.36	7.36
Microtropis ramiflora	Celastraceae	0.62	6.92
Scolopia crenata	Flacourtiaceae	0.62	3.30
Symplocos macrophylla	Symplocaceae	0.92	37.75
Symplocos cochinchinensis	Symplocaceae	2.66	8.63
Syzygium densiflorum	Myrtaceae	21.01	25.97
Vernonia arborea	Asteraceae	10.37	0.48
Species recorded in one plot			
Acronychia pedunculata	Rutaceae	0.87	0
Alseodaphne semecarpifolia	Lauraceae	20.23	0
Beilschmiedia bourdillonii	Lauraceae	1.86	0
Canthium dicoccum	Rubiaceae	20.70	0
Casearia coriacea	Flacourtiaceae	1.52	0
Cinnamomum perrottetii	Lauraceae	1.26	0
Clerodendron viscosum	Verbenaceae	37.54	0
Debregeasia longifolia	Urticaceae	0.67	0
Elaeocarpus munronii	Elaeocarpaceae	4.07	0
Elaeocarpus tuberculatus	Elaeocarpaceae	11.68	0
Eurya nitida	Theaceae	1.60	0
Grewia tiliifolia	Tiliaceae	0.68	0
Hydnocarpus alpina	Flacourtiaceae	2.62	0
Maesa indica	Myrsinaceae	4.76	0
Mallotus tetracoccus	Euphorbiaceae	1.31	0
Mastixia arborea	Cornaceae	7.77	0
Meiogyne pannosa	Annonaceae	1.38	0
Meliosma simplicifolia	Sabiaceae	2.12	0
Miliusa indica	Annonaceae	1.26	0
Symplocos obtusa	Symplocaceae	0.68	0
Viburnum coriaceum	Caprifoliaceae	1.38	0
Viburnum punctatum	Caprifoliaceae	0.81	0
Aglaia apiocarpa	Meliaceae	0	1.71
Apollonias arnottii	Lauraceae	0	8.89
Bhesa indica	Celastraceae	0	1.21
Chionanthus linocieroides	Oleaceae	0	20.47
Glochidion neilgherrence	Euphorbiaceae	0	17.44
Isonandra sp.	Sapotaceae	0	1.31
Litsea oleoides	Lauraceae	0	2.13

Table 16 (Cont'd). Mean Importance index values of tree (gbh ≥ 10.1cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)	
		1910 m	1926 m
Litsea sp.	Lauraceae	0	3.90
Neolitsea scrobiculata	Lauraceae	0	22.19
Nothapodytes nimmoniana	Icacinaceae	0	3.33
Syzygium sp.1	Myrtaceae	0	1.92
Xanthophyllum flavescens	Xanthophyllaceae	0	0.62

The tree seedling phase in the disturbed plot was dominated by *Elaeocarpus munronii*, *Litsea wightiana*, *Gomphandra coriacea*, *Alseodaphne semecarpifolia* and *Syzygium densiflorum* (Table 17). Study also revealed that the contribution by light demanding species to the total IVI was 25.6% and 8% in the seedling and tree phases in the disturbed forest plot respectively. Similarity index value calculated for the disturbed and undisturbed plots for the tree community was 0.56 and when it was 0.345 for the seedling community. Density, basal area and species diversity values for both seedling and tree communities were significantly more in disturbed plot (Table 18).

Table 17. Mean Importance Value Index of tree seedlings (girth < 10.1 cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)	
		1910 m	1926 m
Species recorded in both plots			
Beilschmiedia wightii	Lauraceae	7.66	7.1
Chionanthus linocieroides	Oleaceae	4.05	5.32
Garcinia sp.	Clusiaceae	4.26	13.14
Glochidion neilgherrence	Euphorbiaceae	1.34	2.24
Gomphandra coriacea	Icacinaceae	23.41	9.67
Ilex wightiana	Aquifoliaceae	6.56	4.73
Saprosma fragrans	Rubiaceae	3.53	2.66
Scolopia crenata	Flacourtiaceae	3.57	15.02
Symplocos cochinchinensis	Symplocaceae	8.83	10.49
Syzygium densiflorum	Myrtaceae	18.82	18.77
Species recorded in one plot			
Actinodaphne bourdillonii	Lauraceae	16.30	0
Alseodaphne semecarpifolia	Lauraceae	21.37	0
Canthium dicoccum	Rubiaceae	12.69	0
Celtis tetrandra	Ulmaceae	3.57	0

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Table 17(cont'd). Mean Importance Value Index of tree seedlings (girth < 10.0cm) in shola forest plots in an altitudinal gradient.

Species	Family	Plots at different altitude (in m above msl)	
		1910 m	1926 m
Cinnamomum sulphuratum	Lauraceae	11.70	0
Clerodendrum viscosum	Verbenaceae	5.30	0
Elaeocarpus munronii	Elaeocarpaceae	32.49	0
Eurya nitida	Theaceae	1.19	0
Isonandra lanceolata	Sapotaceae	6.59	0
Litsea wightiana	Lauraceae	26.26	0
Macaranga peltata	Euphorbiaceae	2.99	0
Maesa indica	Myrsinaceae	3.06	0
Mallotus philippensis	Euphorbiaceae	1.53	0
Mastixia arborea	Cornaceae	15.54	0
Meiogyne pannosa	Annonaceae	4.59	0
Neolitsea cassia	Lauraceae	14.77	0
Persea macrantha	Lauraceae	3.02	0
Phoebe lanceolata	Lauraceae	16.07	0
Rapanea thwaitesii	Myrsinaceae	5.58	0
Viburnum coriaceum	Caprifoliaceae	1.08	0
Viburnum punctatum	Caprifoliaceae	6.15	0
Apollonias arnottii	Lauraceae	0	27.22
Aporusa lindleyana	Euphorbiaceae	0	2.31
Canarium strictum	Burseraceae	0	2.47
Cinnamomum macrocarpum	Lauraceae	0	4.98
Cinnamomum wightii	Lauraceae	0	9.34
Eugenia bracteata	Myristicaceae	0	2.53
Ilex denticulata	Aquifoliaceae	0	3.23
Isonandra perottetiana	Sapotaceae	0	2.53
Ligustrum perrottetii	Oleaceae	0	2.53
Litsea oleoides	Lauraceae	0	26.69
Microtropis ovalifolia	Celastraceae	0	9.75
Microtropis ramiflora	Celastraceae	0	30.53
Neolitsea scrobiculata	Lauraceae	0	55.34
Nothapodytes nimmoniana	Icacinaceae	0	8.83
Psychotria sp.	Rubiaceae	0	17.50
Symplocos macrophylla	Symplocaceae	0	5.41

Table 18. Basic information on the tree communities in shola forests located in an altitudinal gradient. N= 3 replicate plots at each location.

Parameters	Plots at different altitude (in m above msl)	
	1910 m	1926 m
Trees		
Number of species	49	39
Density (individuals ha^{-1})	1031±12	1094±7
Basal area (m^2 ha^{-1})	64.56 ±3.25	52.04±2.18
Species Diversity Index value (H)	4.56± 0.78	3.09± 0.25
Species Dominance Index value (C)	0.072± 0.009	0.061± 0.002
Tree seedlings		
Number of species	31	27
Density (individuals ha^{-1})	4474±16	4300± 33
Basal area (m^2 ha^{-1})	2.12±0.35	1.0± 0.12
Species Diversity Index value (H)	4.50± 0.03	4.03±0.06
Species Dominance Index Value (C)	0.055± 0.009	0.097± 0.005

4. Discussion and conclusions

Two major climatic changes predicted in the Indian context include rise in the water table in lowland areas and increase in the atmospheric temperature. Results of the comparative study conducted in low elevation forests in Kerala are discussed to give an insight into the difference in phytosociology of these forests and also to project the possible impact of predicted rise in water level in lowland areas. The Sivapuram forest plot located at 76 m above mean sea level represents a swampy forest patch. Here the family Myristicaceae dominates the tree community. Thus this forest patch can be called as a Myristica swamp. Similar forest type can be seen elsewhere in the Western Ghats (Chandran and Mesta, 2001;Varghese and Kumar, 1997 and Varghese and Menon, 1999). Contribution of species belonging to Myristicaceae to the total IVI of tree community may be different in these forests. For instance, species of Myristicaceae contributed about 48% of the total IVI of tree community in Sivapuram while the contribution by them is 33% and 49% respectively in Myristica swamps in Uttara Kannada district (Chandran and Mesta, 2001), Agasthyamalai region of Kerala (Varghese and Menon, 1999) respectively. Varghese and Kumar (1997) recorded 62% to 74% contributions to the total IVI by the species of Myristicaceae in the Myristica swamps in the southern Kerala. Over-dominance of Myristicaceae and other species such as *Holigama arnottiana*, *Polyalthia fragrans* and *Symplocos racemosa* can be attributed to certain physiological and morphological adaptations to the swampy habitat. Presence of stilt roots, which become flat and woody with age, can be seen in the trees of *Myristica dactyloides* and *Knema attenuata* growing in swamps. In the case of swamp growing trees of *Holigarna arnottiana* breathing roots in the form of loops studded with lenticels protruding into the air from the flooded substratum are common.

It is interesting to note that species such as *Knema attenuata*, *Myristica dactyloides* and *Polyalthia fragrans*, which are dominant in the Myristica swamp of Sivapuram are also dominant in the Kannavam forest which is not a myristica swamp and is located in relatively higher elevation (372 m). However, their contribution to the total IVI is relatively less. In addition, in Kannavam forest, these species do not show any morphological features exhibited by them in the swampy area. However, studies elsewhere indicated that the trees of above-mentioned species have the potential to possess certain morphological features of swamp-growing individuals even in the non-swamp areas (Chandran and Mesta, 2001). Comparatively high species diversity in the Kannavam forest can be attributed to two factors namely, the less dominance of species of Myristicaceae and partitioning of resources by species characteristic to a wide range of elevation. Thus it may be concluded that the Myristica swamps in lowlands of Kerala as in case of at Sivapuram forests represent a distinct plant association. It seems that the climate change in India, which is expected to increase the water table in the low lying areas, may not directly alter habitats and the vegetation structure and composition in myristica swamps located here. However, one can expect certain indirect impacts of water level rise in the coastline due to climate change on these forests. In India, most agriculturally fertile region with rice fields, other than the Indo-Gangetic plain, lies along the Indian Coast line, which are highly vulnerable to inundation and intrusion of salinity. Asthana (1993) estimated that in the absence of protection, 1 m sea level rise on the Indian Coast line is likely to affect a total area of 5763 km^2, and put 7.1 million people at risk. The dominant cost is due to land loss, which accounts for 83% of all damages. In such a situation, possibilities of encroachment of Myristica swamps and their conversion for agriculture, construction, industrial uses, etc., cannot be ruled out.

Palaquium ellipticum, *Mesua ferrea* and *Cullenia exarillata* dominate the relatively undisturbed forest patches at different altitudinal gradients selected to represent medium elevation evergreen forests. According to Pascal (1988), forests dominated by above mentioned three species are the most important among the medium elevation forest types in the Western Ghats both in area and quality. Possible impact of climate change in the medium elevation forests is increase in atmospheric temperature and rainfall. It is also expected that the temperature in a forest patch located at a given altitude could rise to the level of temperature being experienced in the lower altitude forests. In this context, in the medium elevation forest type, comparison of vegetation structure and composition of forest patches located in the relatively higher altitude with those in lower altitude could provide an indication of possible species composition and other phytosociological features in higher altitude forest patches. It may be mentioned here that only 13 species were found to be common in all four plots. This kind of dissimilarity in tree species composition could be due to the difference in gap phase regeneration patterns in these forest patches. In other words, the number, size, frequency and seasonality of natural canopy gap formation determine the regeneration of different species (Chandrashekara and Ramakrishnan, 1994). There could be difference in these parameters in different forest patches and thus species composition may vary. However, as already indicated, in the forest patches along the gradient, a same set of species remained dominant in the tree community. Thus, climate change may not alter the vegetation to an extent where the vegetation alters drastically. However, number of species, density and values obtained for species diversity index, both in tree and seedling communities are more in high altitude forests. Therefore, possible impact of climate change on relatively high altitude forests could be the reduction in species diversity and density of tree and seedling communities. It may be worth mentioning here that a clear trend in increase in density, basal area and contribution to the total species importance index values by *Mesua ferrea* and the family Lauraceae with increase in elevation was noticed. Thus it is also possible to predict that due to climate change, in higher elevation forests, current dominance of *Mesua ferrea* and Lauraceae may be reduced.

As in the case of medium elevation forest type, even in the high altitude forests (shola forests), possible impact of climate change would be increase in atmospheric temperature and rainfall. Here also it could be expected that the temperature in a forest patch located at a given altitude could rise to the level of temperature being experienced in the lower altitude forests. Thus, comparison of vegetation structure and composition of forest patches located in relatively higher altitude with those in lower altitude could provide an indication of possible species composition and other phytosociological features in higher altitude forests. It may be mentioned here that unlike the plots selected at medium elevation forests, shola forest patches along the altitudinal gradient are different from each other in terms of dominant species in their tree communities. As the elevation increases, the dominance of *Cinnamomum perrottetii* and *Microtropis ramiflora* increased respectively in tree and seedling communities. In addition, the species composition in higher altitude forests is significantly different from the plots located in lower elevation shola forests as indicated by the similarity index values obtained for tree and seedling communities. Thus it can be predicted that, due to climate change, in the higher altitude shola forests, the dominance of *Cinnamomum perrottetii and Microtropis ramiflora* may be reduced and species composition may be changed into that being seen in lower altitude sholas. Currently, in higher altitude shola forest patches, density of tree and seedlings are more than those in lower altitude shola forest patches. Even height of the trees is also relatively less. Thus, it can also be predicted that due to climate change, density of trees and seedling and height of the trees could increase in the higher elevation sholas.

In the tropics, several comparative studies were conducted to determine the changes in the environmental conditions in the forest due to disturbance. These studies indicated that in the disturbed forest patches, when compared to undisturbed forests, light intensity and duration would be more. Similarly, when the humidity would be comparatively low, evaporation from the soil surface would be high in the disturbed forests. Thus, in some literature, it is hypothesised that the impact of climate change would be similar to that of disturbance in the forest. It is also mentioned that the studies on floristic diversity, vegetation structure, composition and regeneration patterns in the disturbed forests in a given forest type would help to predict the impact of climate change on these parameters. In this context, in the present study, in each forest type, a disturbed forest and a relatively undisturbed forest patch, located in an almost identical altitude, were compared for their vegetation structure and composition with special reference to tree communities. In each of the three forest types, disturbed and undisturbed forests patches are similar in terms of the occurrence of same set of dominant species of the given forest type. Thus, in the low elevation forest type, disturbed and undisturbed forest patches are similar in terms of the contribution of Myristicaceae to the total IVI of tree community. Similarly, in a forest patch disturbed about 16 years back by selective logging operation and in a relatively undisturbed forest located almost in the same altitude, *Palaquium ellipticum, Mesua ferrea and Cullenia exarillata* are dominant in the tree community. However, in each of the three forest types, unlike in the undisturbed forest patch, in the disturbed forest patch a set of deciduous or light demanding tree species contributed considerably to the total IVI of tree community. A significant difference in terms of species composition, can be observed between undisturbed forest and disturbed forest situated in a given altitude if they were independently compared with the undisturbed forest situated in a relatively lower altitude. Based on all these observations, it is possible to conclude that in a given forest type, in the relatively undisturbed forest patch located at higher altitude, the climate change probably offer competitive advantages over the other species for some species typical to the relatively undisturbed forests. Thus it can be predicted that such species could become over-dominant in forest patches where they are currently not so. On the other hand, microclimatic changes induced by human disturbance are different from the normal climate change. This fact is clear from the present study where it has been demonstrated that the human disturbance alter the vegetation structure and composition of tree community in such a way that light demanding or deciduous tree species, which are generally absent or poorly represented in a relatively undisturbed forests, become dominant. It may also be concluded that if monitoring and detection of vegetation responses to climate changes is to be successful, the monitoring system should be tuned to the location where other disturbances are not likely to override the responses forced by climate changes. Otherwise such responses could easily be misinterpreted as being governed by climate changes rather than by changes in landuse.

5. References

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