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Reinvestigating the permanent plots established by KFRI to measure the dynamics of tree community

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1. Title of the project	: Reinvestigating the permanent plots established by KFRI to measure the dynamics of tree community
2. Objectives	: a) To revisit the Permanent plots established in natural forests of Kerala and re-establish traceable plots. b) To document current structure and composition of tree community
3. Name of the Principal Investigator	: Dr. K A Sreejith
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CONTENTS

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Abstract

More than sixty locations in natural forests of Kerala were revisited to observe and document the current status of permanent plots established by Kerala Forest Research Institute during last three decades. Due to poor maintenance and absence of long-term monitoring, majority of the plots could not be relocated. Those sites which still have signs of plots such as corner stone, tagged/painted trees could be traced and such a way 14 plots were re-established for understanding the current pattern of tree diversity and dynamics. Among these 14 plots, 11 were having the primary data collected during 2002 at the time of its establishment which was compared with current vegetation data. By comparing all the plots in general there was a decrease in total number of individuals from 4982 to 4392 but the total basal area got increased from 453.8 m^2 (2002) to 501.3 m^2 (2012). The mortality rates in majority of plots were higher than the recruitment rate. The mortality was not restricted to any particular girth class and not related to any particular species or girth class. Ten years of monitoring is not sufficient to understand the dynamics of tree community, and to reach a better conclusion therefor to understand the impact of climate change and related factors site specific long-term monitoring and weateher data collection is required.

1. Intoduction

Tropical forests are key elements in the global biogeochemical cycles and well known for complex structural and functional features which has received much attention because of their species richness (Whitmore, 1984), high standing biomass (Bruenig, 1983) and high degree of biological productivity (Jordan, 1983). With its rich abode of biodiversity, tropical forests are regarded as undervalued assets in the race to avert catastrophic climate change and deliver a global and very public benefit by capturing and storing atmospheric carbon. In order to evaluate the complex ecological processes and ecosystem dynamics of tropical forests, a clear well planned execution of long-term strategies are required to ensure conservation of biodiversity and its sustainable utilization. Long-term ecological studies not only enhance our understanding of the relationship between vegetation and environment, but also an essential mechanism to know the response and impact of global climate change. The long-term studies, especially through permanent plots, help to distinguish between pathways, causes and mechanisms of vegetation change and further changes in structure and function of ecosystem (Picket *et al.*, 1987). Permanent plots have now become the basic tool to generate such long-term data on various aspects of ecosystem, especially in species rich forests in the tropical region. Such studies can generate data on forest structure, dynamics, interactions among species, seed dispersal, tree recruitment strategies, causes of rarity, carbon sequestration, wood production, and other important issues both at species and ecosystem level. Permanent sample plots result in precise estimates of change giving greater statistical power to detect change than would a series of temporary sampling units in same habitats. The principal advantage of using permanent instead of temporary sampling units is that for many plant species the statistical tests for detecting change from one time period to the next in permanent sampling units are much more precise and powerful than the tests used on temporary sampling units (Elzinga *et al.*, 1998). Many forests are under great anthropogenic and climate change pressure and require management intervention to maintain the overall biodiversity, productivity and sustainability (Kumar *et al.*, 2002). Understanding species diversity and distribution patterns is important to evaluate the complexity and resources of these forests (Kumar *et al.*, 2006). Long-term and frequent floristic inventory is a necessary prerequisite for much fundamental research in tropical community ecology. Floristic studies are undertaken by many researchers worldwide in different levels following variety of sampling and measurement techniques based on their objectives. The long-term permanent plot studies can potentially provide information about spatio-temporal forest composition, structure and dynamics (Ayyappan and Parthasarathy, 1999) and permanent plot studies are important for conservation and management of tropical forests (Field and Vazquezyanes 1993). A study on tree species diversity, distribution pattern and population structure of tropical forests is ecologically significant besides its usefulness in forest management (Sahu *et al.* 2012). How high diversity in these tropical forests is maintained and how they change over time require long-term monitoring using permanent plots (Condit 1995; Hubbell & Foster 1983; Phillips & Gentry 1994). There is a necessity for collecting long-term data on rates of tropical tree growth, mortality and recruitment over large periods of time in order to improve our limited understanding of forest functioning. (Sundaram and Parthasarathy, 2002). Quantitative floristic inventories based on small sized permanent plots (1 - 2 ha) have been used in recent years to characterize the vegetation in different tropical forests by documenting their structure, composition and diversity (Sagar *et al.* 2003; Smith & Killeen 1995; Strasberg 1996; Parthasarathy 2001). As a part of various research programmes, KFRI established large number of permanent plots in the past (Chandraehekara *et.al*, 1996; Chandrashekara and Jayaram, 2002). Unfortunately these plots were not maintained/monitored. Since long-term data is necessary to know the dynamics of different forest ecosystems of the state, current project was initiated to document the current status of the plots established by KFRI in different natural forest ecosystems of the state so far.

Objectives

1. To revisit the Permanent plots established in natural forests of Kerala and re-establish traceable plots
2. To document current structure and composition of tree community

2. Methodology

Based on the available information on the permanent plots established by KFRI (Chandrashekara and Jayaraman 2002), we could list out more than 60 locations in the State where permanent plots were established in past. We went to each and every location to trace out the plot and for direct verification. After re-establishing the traceable plots, each plot was subdivided into quadrates of 10 x 10 m size for enumeration purpose. Plots were permanently marked at each of their corners with GI pipes. We had taken the gbh measurement of each individuals having size ≥ 10.0 cm Girth at breast height. These data were further analysed (Kershaw, 1973)

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

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

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a given species}}{\text{Sum of frequency of all species}} \times 100$$

$$\text{Relative dominance (R Dom)} = \frac{\text{Total basal area of a given species}}{\text{Total basal area of all species}} \times 100$$

Importance value index (IVI) of a species = RD + RF + R Dom.

The data were also used to calculate different indices by using inventNTFP software (Sivaram *et al.*, 2004)

Mortality and Recruitment rates were calculated using standard procedures (Swaine *et al.*, 1987, Korning and Balslev, 1994, Sheil and May, 1996).

Mortality rate (% year) = [ln (Nb/Ns)] x100/t -1

Recruitment rate (% year) = [ln (Ne/Ns)] x100/t -1

Half-life (year) = ln (0.5)/(annual mortality rate)

Where: Nb = number of individuals in the first sampling; Ns = number of individuals survived between two samplings; Ne = Number of individuals in the second sampling; t = time interval (years) between the two samplings.

3. Results and Discussion

Many of the earlier established permanent smple plots could not be retraced since it left unattended for several years after its establishment. There were no exact boundary, tags/number on trees and other details to trace the established plot in several cases. Few of them (14 locations), have some tagged trees which enabled its re-establishment. During re-establishment, gbh of all marked individuals of above 10 cm gbh was taken; boundaries were marked and each plot mapped for its location details (Fig.1). The current structure and composition of tree community was documented for these 14 plots (Table.1). But the change in vegetation parameters over a period of time were analysed for 11 plots only (except from Pothumala, Alampetty and Mannavan shola) since previous data was not available for rest of the plots.

Table.1 **Location details of re-established permanent plots in natural forests of Kerala**

Sl No.	Plot Code	Locality	Range	Division	Type	Plot Size (ha)	YOE	Year II
1	P1	Sivapuram	Kottiyur	Kannur	EG	0.5	2002	2012
2	P2	Campshed	Kanavam	Wayanad north	EG	0.5	2002	2012
3	P3	Seminary villa	Kanavam	Wayanad north	EG	0.5	2002	2012
4	P4	Thamarassery 4th mile	Thamarassery	Kozhikode	EG	0.5	2002	2012
5	P5	Thamarassery 8th mile	Thamarassery	Kozhikode	EG	0.5	2002	2012
6	P6	Nadukani	Vazhikadavu	Nilambur north	EG	0.5	2002	2012
7	P7	Pakuthipalam	Nelliyampathy	Nemmara	EG	0.5	2002	2012
8	P8 #	Pothumala	Nelliyampathy	Nemmara	EG	1	1998	2012
9	P9	Vellanipacha	Pattikad	Peechi WLS	EG	0.5	2002	2012
10	P10 #	Allempetty	Chinnar	Chinnar WLS	DDF	1	1998	2012
11	P11 #	Mannavan shola	Kanthallur	Eravikulam NP	Shola	1	1998	2012
12	P12	Achankovil(10th mile)	Achankovil	Achankovil	EG	0.5	2002	2012
13	P13	Palaruvi	Aryankavu	Thenmala	EG	0.5	2002	2012
14	P14	Vellatank	Thenmala	Thenmala	SEG	0.5	2002	2012

* EG- Evergreen, SEG- Semi evergreen DDF- Dry deciduous, YOE- Year of establishment, Year II- Year of Re-etablishemnt. # Change in vegetation could not be analysed since primary data on first enumeration is not available.

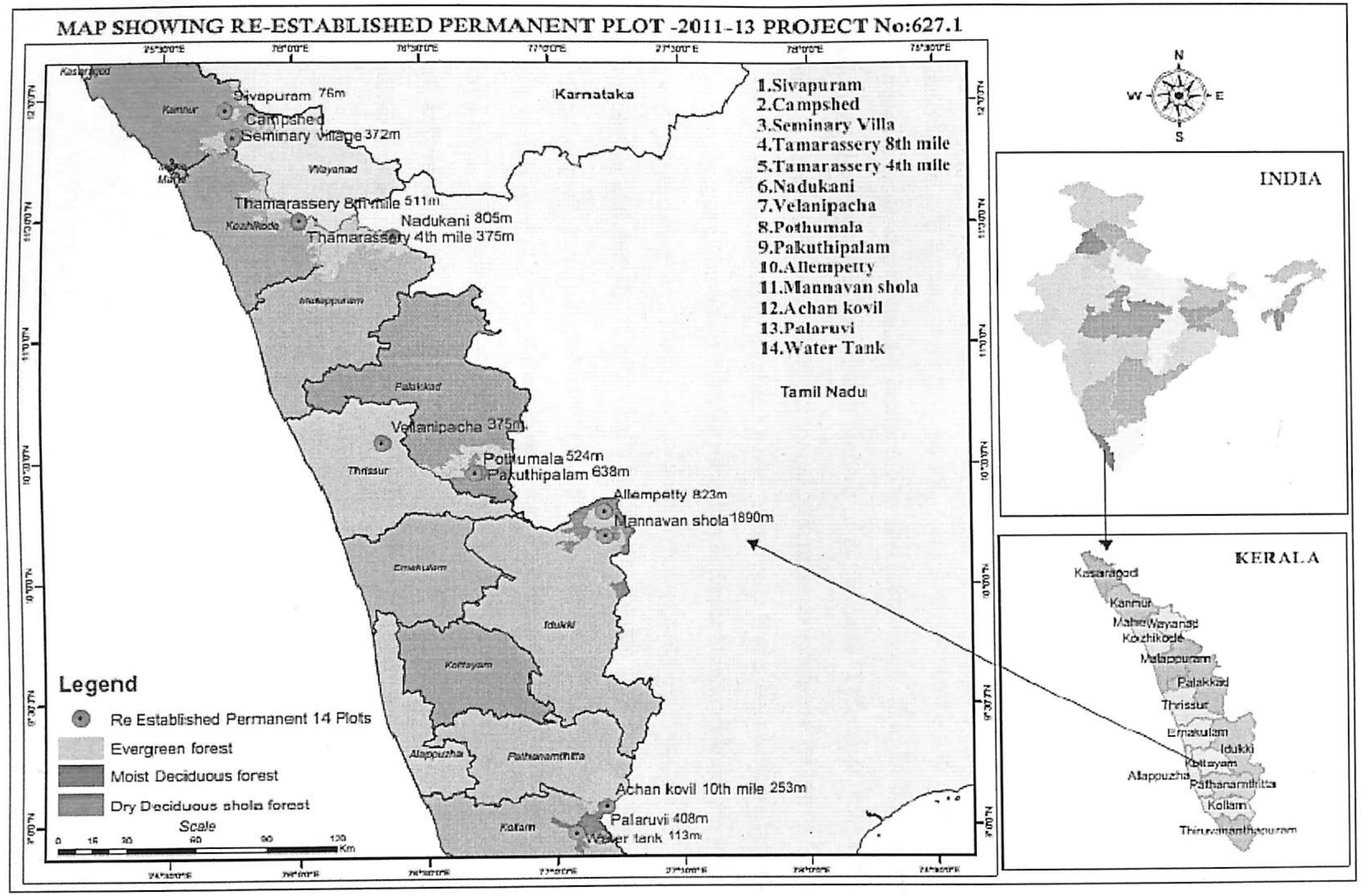

Figure.1: Distribution map of re-established permanent plots in natural forests of Kerala

While analyzing the data from 11 plots, it was found that a total of 4392 individuals of 167 species were enumerated during second inventory after re-establishment. This shows a decreasing trend both in terms of number of individuals and number of species which were 4982 and 172 respectively in firest inventory. Basic change in vegetation parameters are summarized in (Table.2). Number of species was reduced in all plots where previous data is available, except in two plots (Vellanipacha and Pakuthipalam) (Table.7&8). Decrease in the number of species was ranging from 1-5 and was high in Champshed and 4thMile and low in Sivapuram and Vellatanku. Meanwhile number of species was increased by 4 in Pakuthipalam and by 3 in Vellanipacha.

Number of individuals per hectre (densisty) varied from 396 (Vellatank) to 1272 (8th Mile) which got reduced in several plots when compared to first sampling (Table.2); It is noteworthy that only two plots showing slight increase in number of individuals (Vellanipacha and 4th mile). In general, there is decrease in number of individuals. Increase in death and failure of substantial recruitment comparing to mortality (Table.3) also observed. Signs of artificial logging and cutting of trees were not at all common in these plots hence direct human disturbance may not be responsible for decrease in density. Since the system is dynamic naturally there will be change in the number of species and density of individuals but drastic change with reference to particular site, species may require in depth site specific, species specific study and analysis. Drastic decrease was noted in several plots (Pakuthipalam and 8th Mile plots, both showed decrease of 192 individual's ha^{-1}). The only sign of increase in density was from Vellanipacha and 4th Mile but only by 18 individual's ha^{-1}. This decrease in number of individuals may be considered as an impact of climate change, how ever it needs long term data to confirm.

3.1 Density

Changes in tree density are widely used to indicate changes in forest structure and composition locally (Tucker *et al.*, 2008; Karna *et al.*, 2010; Nagendra *et al.*, 2010), and globally (FAO, 2006) and the species richness and diversity provide important indicators of ecosystem stability and resilience (Schindler *et al.*, 2010). Since plot based sampling keeps areal unit of sampling constant, a greater number of stems are likely tosupport a greater number of species (Gotelli and Colwell, 2001). Hence according to them there is a positive correlation exist in number of individuals and number of species. But based on present study, the change in number of species may not be always correlated with change in density. For instance in Pakuthipalam the number of species increased even large number individuals died and total density decreased drastically. On the other hand, in Vellanipacha three species were added while density remains almost same. In 4th mile, four species were reduced while density remains same.The importance of plant population density in governing patterns of resource competition and availability and hence rates of recruitment, growth and mortality is well established (McDowell *et al.*, 2006; Adams *et al.* 2009). In forest ecosystems tree population density is used as an indirect measure of competition intensity, and it influences growth and mortality in forests around the world (Hille *et al.*, 2002). Since there is a general trend of decreasing density by reducing total number of individuals by 12% and there was no sign of direct human disturbance, the possible impact of climate change may be tested with the support of site-specific climate data and long-term results. Species dominance was increased in most of the study sites, meanwhile Pakuthipalam, Palaruvi, Vellatnku, Vellanipacha and 4th mile showed decreasing trend. This indicates majority of the plots are still in successional stage.

3.2. Basal Area

Basal area generally showed increase in most of the cases especially in Vellanipacha having the highest increase with 12.18m^2/ha where as plots at Campshed and Seminarivilla showed decrease of 7.65 m^2/ha and 2.45 m^2/ha respectively. Total basal area of the tree community of the permanent plots was 453.8 m^2 in 2002 which has been increased to 501.3 m^2 during second inventory. This is more intresting since this 11% increase in basal area happens when total density decreased by 12%. This increase in basal area even after the decrease in density clearly indicates the carbon sequestration potential of natural forests of Kerala.

3.3. Mortality and Recruitment

During the second enumeration, the annual mortality rate is found higher when compared to the recruitment rate in most of the cases (Table.3&4). Most number of individual death was found in Pakuthipalam and the percentage of death was higher when compared to the recruited individuals. Least number of individual deaths was found in Vellanipacha while recruitment of individuals and percentage of recruitment of individuals was found high in Seminarivilla plot. When the death percentage and the recruitment percentage of all the plots are compared it is found that the death percentage was high in Sivapuram and recruitment rate was high in 4th Mile (Table.3&4). Some long-term studies on tree population dynamics through permanent plots revealed that in relatively undisturbed forests, the community maintains stability inspite of luctuations in mortality and recruitment rates of some populations (Philips, 1996; Sheil *et.al.*, 2000; Kohyama *et.al.*, 2003). But this unstability in stands where there is no sign of disturbance indicates the impact of past disturbance in the stand and due to the same the stand is still in the process of stablilization.

Table.2: Basic vegetation comparison of re-established plots (The 2002 values are in Paranthesis)

Plot code	Forest type*	Location	Number of species	Number of Individuals	Density (Individuals/ha)	Basal area (m2/ha)	H*	C*	Mergelef's Index(R1)	Menhinick's Index(R2)
P1	EG	Sivapuram	28 (29)	322 (403)	644 (806)	38.82 (34.25)	2.13 (2.23)	0.210 (0.188)	4.675 (4.667)	1.561 (1.444)
P2	EG	Campshed	42 (47)	340 (376)	680 (752)	46.43 (54.08)	2.79 (2.93)	0.117 (0.105)	7.033 (7.757)	2.277 (2.423)
P3	EG	Seminari villa	54 (56)	414 (442)	828 (884)	44.41 (46.86)	3.18 (3.37)	0.065 (0.054)	8.795 (9.193)	2.653 (2.711)
P4	EG	4th mile	38 (42)	241 (232)	482 (464)	48.29 (45.49)	2.59 (2.68)	0.150 (0.152)	6.745 (7.711)	2.447 (2.823)
P5	EG	8th mile	63 (66)	636 (732)	1272 (1464)	46.44 (42.22)	2.91 (3.06)	0.119 (0.101)	9.604 (10.006)	2.498 (2.476)
P6	EG	Nadukani	56 (58)	477 (493)	954 (986)	53.89 (46.88)	3.11 (3.19)	0.074 (0.066)	8.917 (9.192)	2.564 (2.612)
P7	EG	Pakuthipalam	51 (47)	456 (552)	912 (1104)	58.84 (48.09)	3.18 (2.99)	0.0632 (0.084)	8.166 (7.444)	2.388 (2.043)
P8	EG	Pothumala	31	1522	1522	76.18	2.86	0.071	4.094	0.794
P9	EG	Vellanipacha	61 (58)	589 (580)	1178 (1160)	42.75 (30.57)	3.38 (3.35)	0.051 (0.054)	9.406 (9.743)	2.513 (2.615)
P10	DDF	Alampetty	28	582	582	22.92	2.047	0.211	4.24	1.161
P11	Shola	Mannavan shola	35	823	823	45.37	2.71	0.0952	5.0648	1.22
P12	EG	10th mile	55 (57)	284 (331)	568 (662)	44.34 (38.31)	3.49 (3.59)	0.038(0.037)	9.559(10.168)	3.263(3.297)
P13	EG	Palaruvi	65 (69)	437 (509)	874 (1018)	49.78 (40.51)	3.62 (3.60)	0.036 (0.042)	10.5264 (11.392)	3.109 (3.191)
P14	SEG	Vellatanku	56 (57)	198 (233)	396 (466)	27.31 (26.54)	3.45 (3.49)	0.042 (0.043)	10.4003 (10.823)	3.979 (3.931)

*** SEG= Semi-evergreen Forests, EG= Evergreen Forests, DDF= Dry Deciduous Forests, MDF= Moist Deciduous Forests, Shola= Shola, H= Shannon's index of species diversity, C= Simpsons index of Species dominance.**

Table.3 Recruitment and mortality rate of tree community

Plot Code No.	Location	Mortality rate (% year-1)	Recruitment rate (% year-1)
P1	Sivapuram	2.306	0.062
P2	Campshed	2.735	1.729
P3	Seminari villa	2.448	1.794
P4	4th mile	1.237	1.617
P5	8th mile	1.501	0.094
P6	Nadukani	1.137	0.807
P7	Pakuthipalam	3.146	1.235
P9	Vellanipacha	0.386	0.541
P12	10th mile	2.299	0.768
P13	Palaruvi	2.896	1.371
P14	Vellatanku	2.581	0.953

Table.4 **Recruitment and Death Percentage**

Plot Code No.	Location	Recruitment		Death	
		Number	Percentage	Number	Percentage
P1	sivapuram	2	0.62	83	20.59
P2	campshed	54	15.88	90	23.93
P3	seminari villa	68	16.42	96	21.71
P4	4th mile	36	14.93	27	11.63
P5	8th mile	6	0.94	102	13.93
P6	Nadukani	37	7.75	53	10.75
P7	Pakuthipalam	53	11.62	149	26.99
P9	Vellanipacha	31	5.26	22	3.79
P12	10th mile	21	7.394	68	20.54
P13	Palaruvi	56	12.81	128	25.14
P14	Vellatanku	18	9.09	53	22.74

3.4. Species level Importance Value Index

Importance Value Index of species (species IVI) when compared to the old data didn't showed much variation. In most of the plots the species which showed high IVI remains the same. In certain plots during the second phase the top listed species were changed. In 8th Mile, *Palaquium ellipticum* came to the top in terms of IVI which was not there in the top three, on the othe other hand, *Knema attenuate* which occupied 3rd position in the first enumeration were not found top three; Palaquium is one of the primary species which represent undisturbed medium evergreen forest hence this change may be considered as a positive sign towards the climax stage of the forest patch. Where as in the case of Nadukani, Palaruvi and Vellatanku in some cases, the top three species were the same but their position got changed which may be due to natural dynamics or a gradual shifting of dominance which need to be observed and confirmed by long-term monitoring. In the case of Pakuthipalam, *Fahrenheitia zeylanica* came to the 3rd position which was not in the first three position during the first enumeration at the same time *Croton malabaricus* which was in 2nd position during the first enumeration was drop out from the first three places. *Croton malabaricus* is a secondary species hence its decrease in contribution of total IVI indicates progressive succession.

3.5. Girth class distribution

The girth class distribution of tree community is a parameter that can assist in assessing the status and quality of the forest (Richards, 1996). According to Mori *et.al.*, (1983), the size class of tree community in relatively undisturbed forest showas a negative exponential distribution with clear preponderance of stems of small girth classes. Here too, in majority of cases, it took a shape of an inverse J curve, characteristic to relatively undisturbed forest patch. Moreover, girth classs distribution pattern did not differ significantly between two study periods (Figure 4), indicating that the tree community has been structurally stable during study period and decrease in total density is proportionate to the number of individuals in each girth class But there are plots where less number of individuals in lower girth class for eg. 4th mile but data indicates that the representation of lower girth class during 2012 at 4th mile was increased from 2002 from 31 indivudals to 62 (Figure. 2& 3).

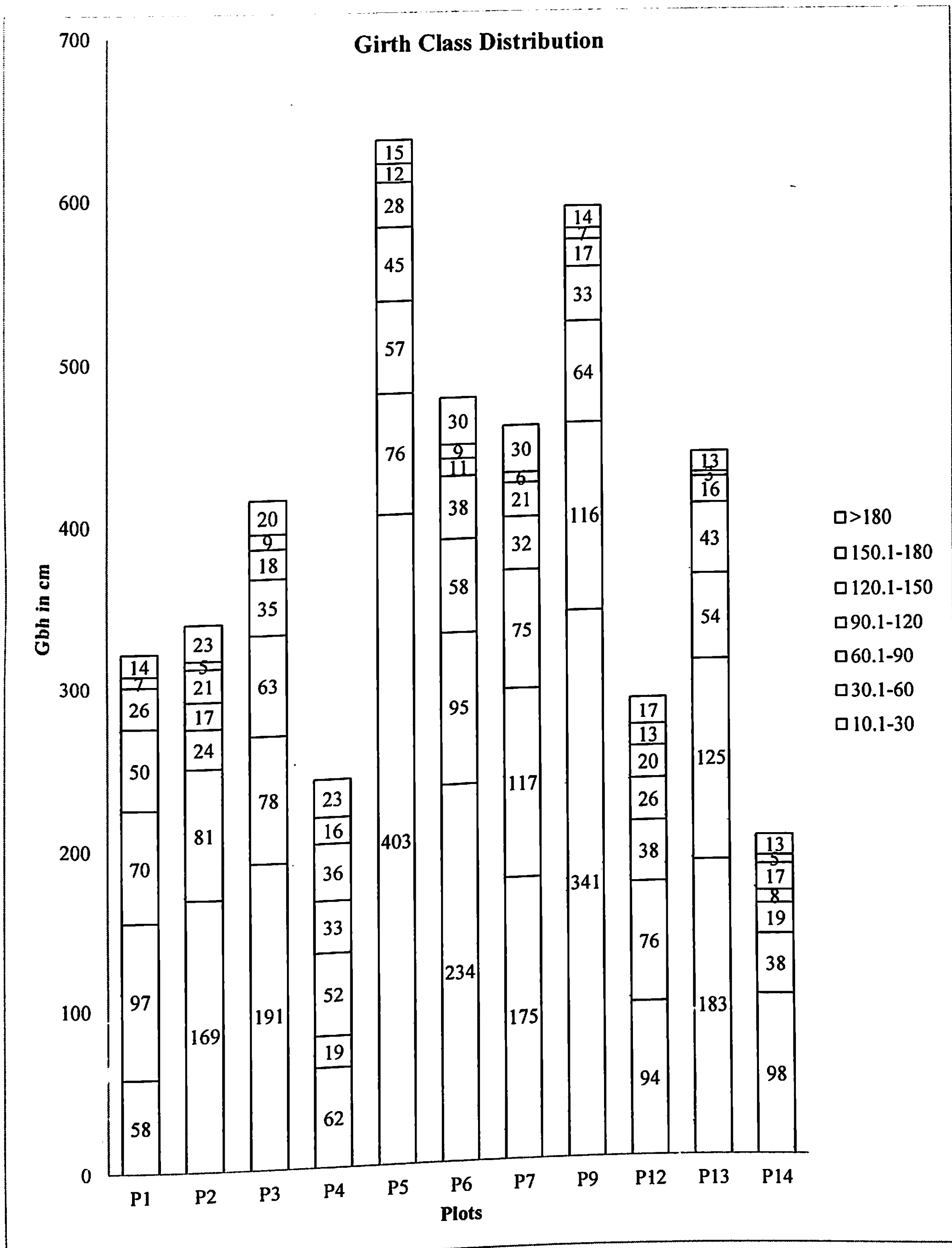

Figure.2: Girth Class Distribution pattern (2012)

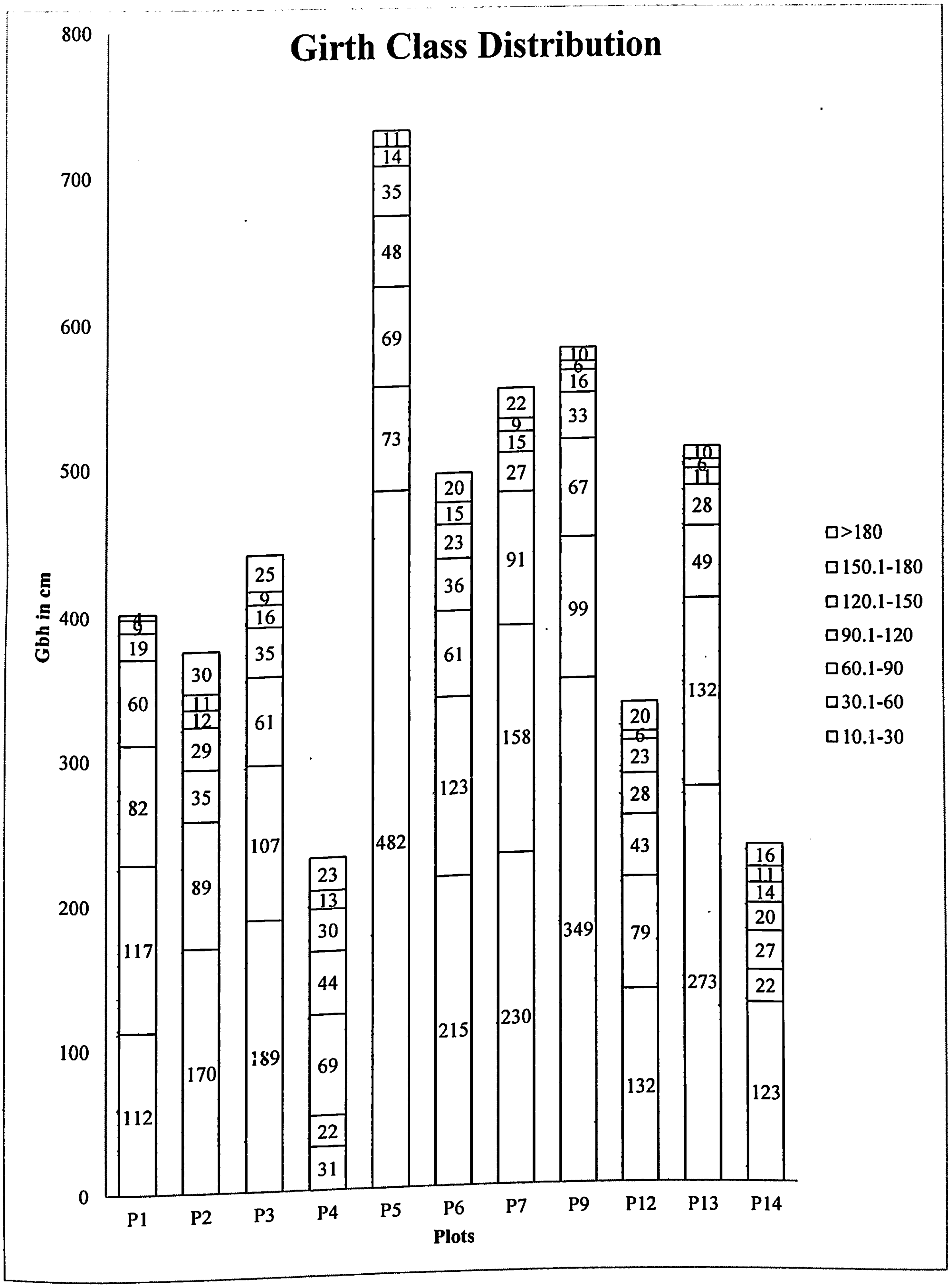

Figure.3: Girth Class Distribution pattern (2002)

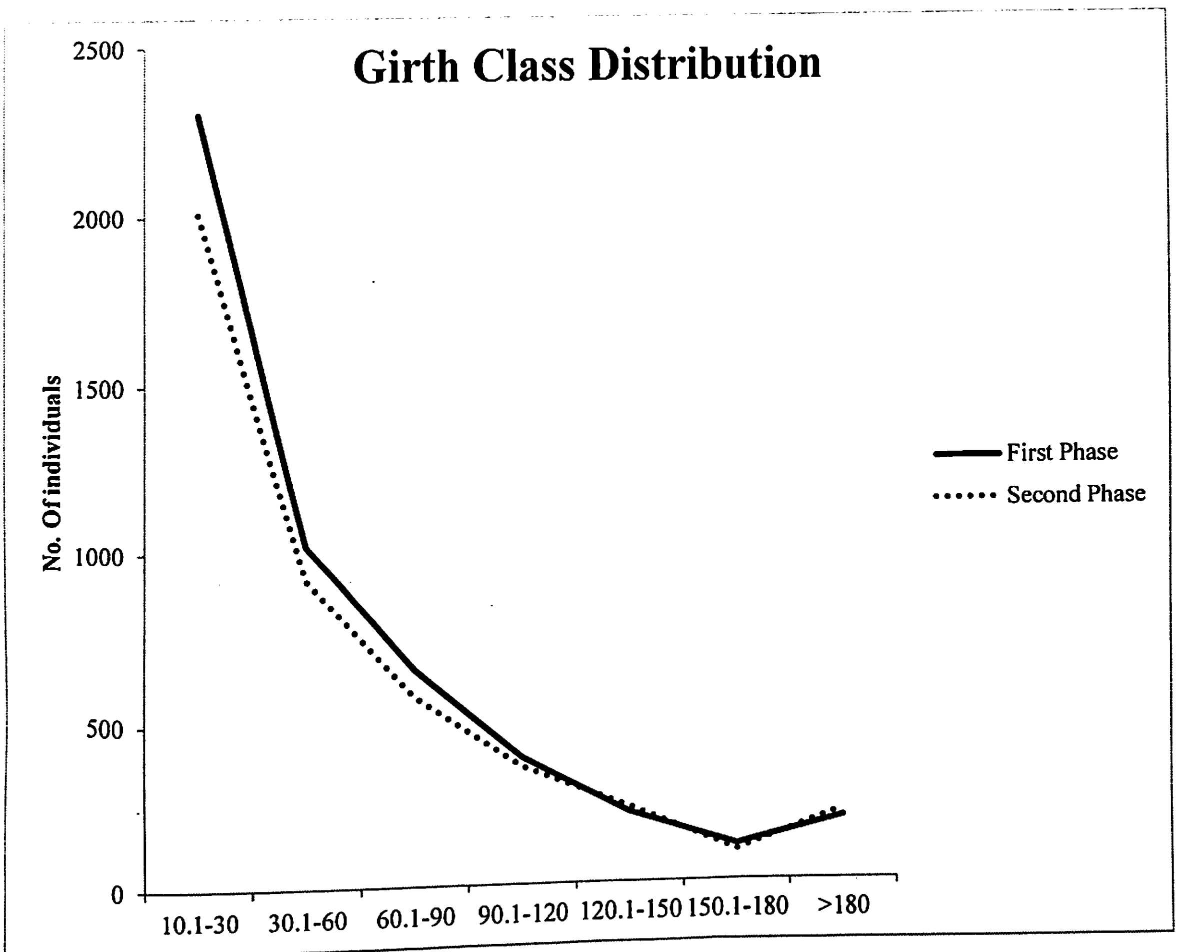

Figure.4: Girth Class Distribution pattern in 2002 (First Phase) and 2012 (Second Phase)

Analysis of Girth class distribution pattern of dead individuals is a clear indication of the factors responsible for death, for examble a reduction in number of individuals specific to particular girth class; a reduction in number of individuals of a particular species are indicaters of species level or girth class level change. While analysing this it did not show any specific species, specific girth class factor which itself indicates that a common factor like climate change may be responsible for this change. (Figure.4)

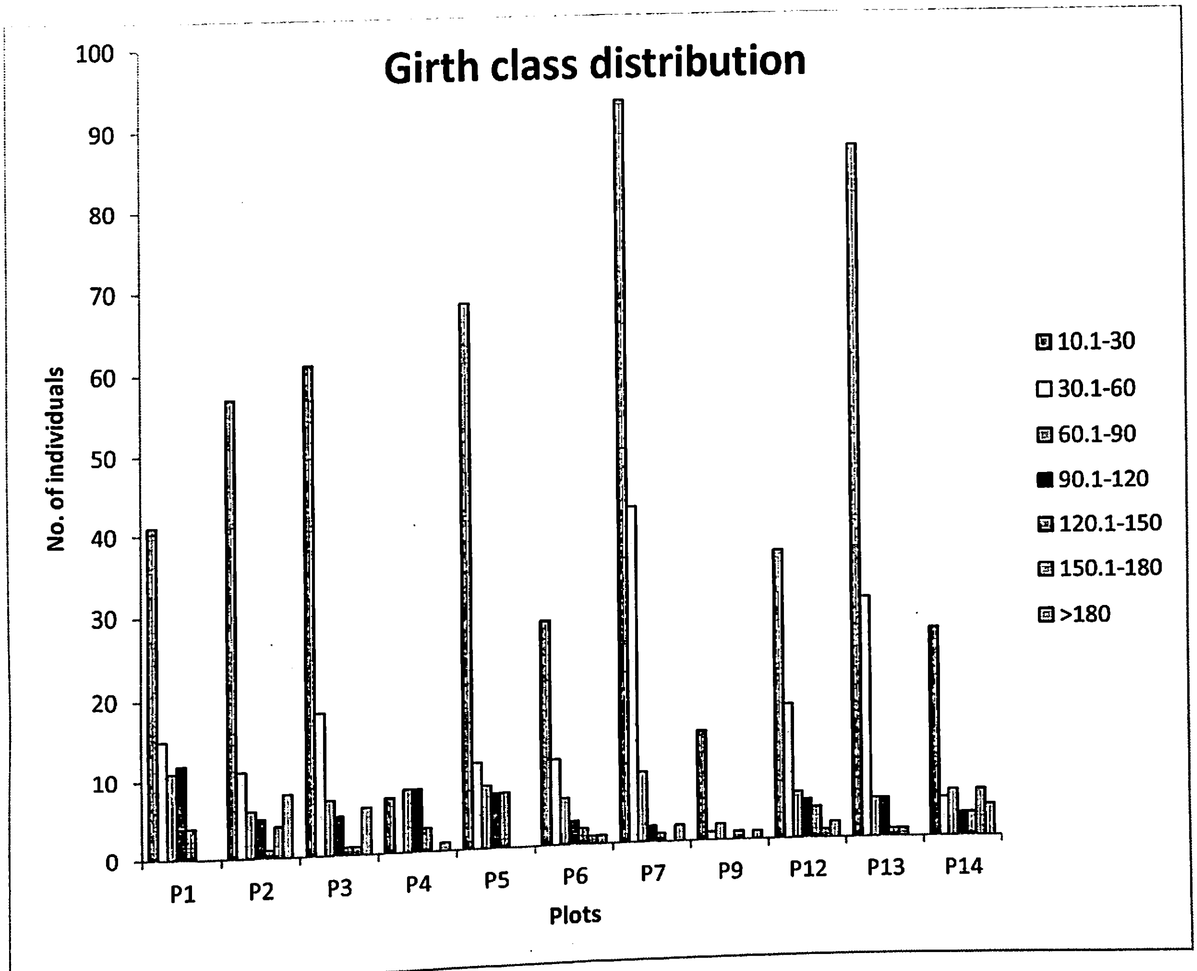

Figure.5: Girth class distribution of dead individuals

4.Conclusions and Recommendations

- Species richness and density showed decreasing trend in majority of cases. But in addition to vegetation data, continuous weather data is also required from each site to understand the impact weather on vegetaton dynamics.
- In majority of cases, death rate is 2 or 3 times greater than that of recruitment rate; site specific and species specific indepth studies are required to understand the cause and to mitigate the same. In general, dead individuals were from all girth class with almost equal proportion to its live individuals that are death of individuals can not be assigned to any species specific issues like over harvesting, diseases etc.
- It is note worthy that, even in 12% reduction of total number of individuals there is an increase of 11% in total basal area which indicates the carbon sequestration potential of natural forests in climate change scenario.
- Since large number of plots established by KFRI during past could not be relocated due to poor maintenance, it is suggested a continuous long-term programme for the maintenance and monitoring of existing permanent plots in the natural forests of Kerala.
- It is also recommended to collect girth increment data at regular interval by which the carbon sequestration potential of major forest types can be tested statistically.
- Since majority of plots maintained are evergreen and moist deciduous forests were poorly represented, more number of 1 ha. plots to be established and monitored in moist deciduous forests of Kerala to understand its diversity and dynamics.
- It is also suggested to monitor the population dynamics of threatened tree species through permanent sample plots in their specific locality.
- There is large number of sacred serves in Kerala; a network of permanent plots for its long-term monitoring will generate valuable information on sacred groves of the state.
- This study shows that as far as dynamics of tree community is concerned, ten year is too short for a significant change in vegetation hence the long-term data collection at regular intervals needs to be ensured.
- It is suggested to establish a Permanent plot network in the state in association with Kerala Forest Department and other allied agencies with a common protocol.

- In depth studies on regeneration status of stand as a whole and on selected species is suggested to predict the change in species composition in near future.
- Developing software to map individual trees in each plot is suggested by which more information can be gathered on species distribution pattern and species association.
- New plots are needed to be established to represent unique ecosystems like myristica swamps, sacred groves, mangroves, grasslands etc.
- Site specific climate data should be collected on long-term basis to predict the impact of climate change in the dynamics of natural forest ecosystems.
- These plots can generate large amount of scientific data on various aspects of forest ecosystem and its function hence multidisciplinary studies are suggested using this permanent plot platform.
- Long-term monitoring through permanent sample plots can thus provide the essential empirical basis for understanding ecosystem structure and dynamics which typically extend over many generations of researchers which require continued institutional support, preferably guaranteed by legislation to ensure that they are not abandoned at all.

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6. Appendix

6.1. Species list of eleven 0.5ha plots

Sl.no	Species	Plot code										
		P1	P2	P3	P4	P5	P6	P7	P9	P12	P13	P14
1	*Actinodaphne bourdillonii*Gamble		✓					✓			✓	
2	*Actinodaphne hookeri* Meisn.	✓					✓		✓			
3	*Actinodaphne lawsonii* Gamble				✓							
4	*Actinodaphne gullavara* (Buch.-Ham. ex Nees) M.R.Almeida					✓	✓					
5	*Aglaia lawii* (Wight) C.J.Saldanha		✓	✓	✓	✓		✓	✓			
6	*Aglaia tomentosa* Teijsm. & Binn.							✓				
7	*Agrostistachys borneensis* Becc.							✓				
8	*Albizia odoratissima* (L.f.) Benth.											✓
9	*Alseodaphne semecarpifolia* Nees			✓								
10	*Alstonia scholaris* (L.) R. Br.	✓		✓						✓	✓	✓
11	*Antiaris toxicaria* Lesch.			✓	✓	✓				✓	✓	
12	*Antidesma alexiteria* L.						✓					
13	*Antidesma montanum* Blume						✓	✓	✓		✓	✓
14	*Aphanamixis polystachya* (Wall.) R.Parker								✓	✓		
15	*Aporosa cardiosperma* (Gaertn.) Merr.	✓										✓
16	*Artocarpus heterophyllus* Lam.			✓		✓		✓				
17	*Artocarpus hirsutus* Lam.	✓	✓	✓	✓		✓			✓	✓	
18	*Atalantia racemosa* Wight ex Hook.									✓	✓	
19	*Atalantia wightii* Yu.Tanaka					✓			✓			
20	*Baccaurea courtallensis* (Wight) Müll.Arg.		✓	✓	✓	✓	✓	✓		✓	✓	✓
21	*Bischofia javanica* Blume			✓		✓	✓	✓			✓	
22	*Bombax ceiba* L.								✓	✓	✓	✓
23	*Bridelia retusa* (L.) A.Juss.							✓				✓
24	*Calophyllum polyanthum* Wall. ex Planch. & Triana		✓		✓		✓					

25	*Canarium strictum* Roxb.		✓			✓		✓		✓		
26	*Caryota urens* L.			✓		✓	✓		✓		✓	
27	*Casearia rubescens* Dalzell								✓			
28	*Cassia fistula* L.											✓
29	*Cassine glauca* (Rottb.) Kuntze							✓				
30	*Celtis philippensis* Blanco										✓	
31	*Chionanthus albidiflorus* Thwaites						✓				✓	
32	*Chionanthus mala-elengi* (Dennst.) P.S.Green			✓							✓	
33	*Cinnamomum malabatrum* (Burm.f.) J.Presl	✓	✓	✓	✓	✓	✓					✓
34	*Cleidion javanicum* Blume									✓		
35	*Croton malabaricus* Bedd.		✓	✓		✓	✓	✓		✓	✓	
36	*Cullenia exarillata* A.Robyns					✓	✓	✓				
37	*Cynometra travancorica* Bedd.								✓			
38	*Dillenia pentagyna* Roxb.											✓
39	*Dimocarpus longan* Lour.		✓		✓	✓		✓	✓	✓	✓	✓
40	*Dimorphocalyx beddomei* (Benth.) Airy Shaw								✓			
41	*Diospyros bourdillonii* Brandis	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
42	*Diospyros buxifolia* (Blume) Hiern								✓	✓		
43	*Diospyros candolleana* Wight		✓	✓			✓		✓		✓	
44	*Diospyros crumenata* Thwaites					✓					✓	
45	*Diospyros foliolosa* Wall. ex A.DC.									✓	✓	
46	*Diospyros oocarpa* Thwaites	✓	✓		✓	✓	✓		✓	✓		
47	*Diospyros paniculata* Dalzell			✓		✓	✓		✓	✓	✓	✓
48	*Diospyros ebenum* J.Koenig ex Retz.							✓				
49	*Dipterocarpus indicus* Bedd.					✓						
50	*Drypetes oblongifolia* (Bedd.) Airy Shaw										✓	
51	*Drypetes venusta* (Wight) Pax & K.Hoffm.		✓	✓	✓		✓	✓	✓			
52	*Dysoxylum malabaricum* Bedd. ex C.DC.		✓	✓							✓	✓

53	*Dysoxylum gotadhora* (Buch.-Ham.) Mabb.								✓			
54	*Elaeocarpus tuberculatus* Roxb.	✓	✓									
55	*Elaeocarpus hygrophilus* Kurz								✓			
56	*Erythrina variegata* L.											✓
57	*Erythroxylum moonii* Hochr.								✓			
58	*Euonymus indicus* B.Heyne ex Wall.								✓			
59	*Ficus beddomei* King					✓						
60	*Ficus exasperata* Vahl							✓		✓	✓	✓
61	*Ficus hispida* L.f.										✓	
62	*Ficus nervosa* B.Heyne ex Roth	✓	✓	✓	✓					✓	✓	✓
63	*Ficus racemosa* L.							✓				
64	*Filicium decipiens* (Wight & Arn.) Thwaites		✓	✓								
65	*Flacourtia montana* J.Graham		✓	✓		✓	✓				✓	✓
66	*Garcinia gummi-gutta* (L.) Roxb.			✓		✓	✓			✓		
67	*Garcinia morella* (Gaertn.) Desr.		✓	✓		✓	✓					
68	*Garcinia talbotii* Raizada ex Santapau		✓				✓		✓	✓		
69	*Goniothalamus cardiopetalus* (Dalzell) Hook.f. & Thomson						✓					
70	*Grewia tiliifolia* Vahl								✓	✓	✓	✓
71	*Harpullia arborea* (Blanco) Radlk.			✓								✓
72	*Heritiera papilio* Bedd.							✓				
73	*Holigarna arnottiana* Hook.f.	✓		✓	✓	✓	✓	✓				
74	*Holigarna ferruginea* Marchand							✓				
75	*Holigarna grahamii* (Wight) Kurz		✓	✓	✓	✓	✓			✓	✓	
76	*Holigarna nigra* Bourd.		✓		✓	✓						
77	*Hopea parviflora* Bedd.	✓							✓	✓	✓	✓
78	*Hopea ponga* (Dennst.) Mabb.					✓						
79	*Hopea racophloea* Dyer						✓				✓	
80	*Humboldtia brunonis* Wall.		✓		✓							
81	*Hunteria zeylanica* (Retz.) Gardner ex Thwaites								✓			

82	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	✓		✓	✓	✓	✓			✓	✓	✓
83	*Isonandra lanceolata* Wight					✓		✓				
84	*Isonandra montana* (Thwaites) Gamble										✓	
85	*Ixora nigricans* R.Br. ex Wight & Arn.	✓		✓	✓	✓			✓		✓	✓
86	*Kingiodendron pinnatum* (DC.) Harms		✓		✓	✓	✓		✓	✓	✓	✓
87	*Knema attenuata* Warb.	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
88	*Lagerstroemia microcarpa* Hance			✓					✓	✓		✓
89	*Lannea coromandelica* (Houtt.) Merr.											✓
90	*Leea indica* (Burm. f.) Merr.							✓				
91	*Lepisanthes erecta* (Thwaites) Leenh.							✓				
92	*Lepisanthes deficiens* Radlk.								✓	✓	✓	
93	*Leptonychia caudata* Burret						✓					
94	*Litsea coriacea* Hook.f.					✓						
95	*Litsea floribunda* Gamble			✓	✓			✓				
96	*Litsea laevigata* Gamble			✓		✓	✓		✓	✓	✓	
97	*Litsea nigrescens* Gamble								✓			
98	*Lophopetalum wightianum* Arn.	✓										
99	*Macaranga peltata* (Roxb.) Müll.Arg.		✓					✓		✓	✓	✓
100	*Mallotus beddomei* Hook.f.					✓		✓	✓	✓	✓	✓
101	*Mallotus philippensis* (Lam.) Müll.Arg.		✓	✓		✓				✓		✓
102	*Mallotus tetracoccus* (Roxb.) Kurz										✓	
103	*Mallotus polycarpus* (Benth.) Kulju & Welzen				✓							
104	*Mallotus resinosus* (Blanco) Merr.				✓		✓				✓	
105	*Mammea suriga* (Buch.-Ham. ex Roxb.) Kosterm.										✓	
106	*Mangifera indica* L.	✓	✓	✓	✓	✓	✓	✓		✓		✓
107	*Mastixia arborea* (Wight) C.B.Clarke							✓				
108	*Meiogyne pannosa* (Dalzell) J. Sinclair				✓		✓		✓			
109	*Meiogyne ramarowii* (Dunn) Gandhi			✓		✓			✓	✓	✓	

110	*Melia azedarach* L.									✓		✓
111	*Memecylon umbellatum* Burm. f.								✓			
112	*Mesua ferrea* L.					✓	✓	✓			✓	✓
113	*Miliusa tomentosa* (Roxb.) J.Sinclair								✓			
114	*Murraya paniculata* (L.) Jack										✓	
115	*Myristica dactyloides* Gaertn.	✓						✓				
116	*Myristica malabarica* Lam.	✓	✓	✓	✓	✓	✓		✓		✓	
117	*Neolamarckia cadamba* (Roxb.) Bosser											✓
118	*Nothopegia beddomei* Gamble		✓									
119	*Nothopegia travancorica* Bedd. ex Hook.f.											✓
120	*Olea dioica* Roxb.						✓		✓			✓
121	*Orophea erythrocarpa* Bedd.										✓	
122	*Otonephelium stipulaceum* (Bedd.) Radlk.		✓	✓	✓	✓	✓	✓				
123	*Pajanelia longifolia* (Willd.) K.Schum.										✓	
124	*Palaquium ellipticum* (Dalzell) Baill.		✓	✓		✓	✓	✓				
125	*Paracroton pendulus* (Hassk.) Miq.				✓	✓	✓	✓				
126	*Persea macrantha* (Nees) Kosterm.	✓	✓						✓			
127	*Phaeanthus malabaricus* Bedd.					✓						✓
128	*Polyalthia coffeoides* (Thwaites) Hook.f. & Thomson			✓		✓	✓	✓				
129	*Polyalthia fragrans* (Dalzell) Benth. & Hook. f.	✓		✓	✓	✓	✓		✓	✓	✓	✓
130	*Prunus ceylanica* (Wight) Miq.	✓				✓	✓			✓	✓	
131	*Pseudaidia speciosa* (Bedd.) Tirveng.								✓			
132	*Psychotria macrocarpa* Hook.f.						✓					
133	*Pterospermum diversifolium* Blume							✓		✓		
134	*Pterospermum reticulatum* Wight & Arn.	✓							✓			✓
135	*Pterospermum rubiginosum* B.Heyne ex Wall.		✓				✓			✓		✓
136	*Pterygota alata* (Roxb.) R.Br.							✓				

137	*Rinorea bengalensis* (Wall.) Gagnep. in Humbert					✓						✓
138	*Sapindus trifoliatus* L.			✓						✓		✓
139	*Schleichera oleosa* (Lour.) Merr.											✓
140	*Scolopia crenata* Clos					✓						
141	*Spondias pinnata* (L. f.) Kurz								✓	✓	✓	
142	*Sterculia guttata* Roxb. ex G.Don	✓		✓					✓	✓		✓
143	*Strychnos nux-vomica* L.								✓			
144	*Symplocos macrophylla* Wall.										✓	
145	*Symplocos racemosa* Roxb.	✓		✓								
146	*Syzygium caryophyllatum* (L.) Alston					✓						
147	*Syzygium densiflorum* Wall. ex Wight & Arn.						✓				✓	
148	*Syzygium gardneri* Thwaites		✓				✓					
149	*Syzygium hemisphericum* (Wight) Alston		✓				✓			✓	✓	
150	*Syzygium laetum* (Buch.-Ham.) Gandhi								✓			
151	*Syzygium lanceolatum* (Lam.) Wight & Arn.					✓						
152	*Syzygium mundagam* (Bourd.) Chithra						✓					
153	*Syzygium munronii* (Wight) N.P.Balakr.			✓		✓						
154	*Tabernaemontana alternifolia* L.			✓							✓	✓
155	*Terminalia bellirica* (Gaertn.) Roxb.				✓	✓	✓					✓
156	*Terminalia paniculata* Roth											✓
157	*Tetrameles nudiflora* R. Br.							✓	✓	✓		✓
158	*Toona ciliata* M.Roem.		✓	✓		✓	✓			✓	✓	
159	*Trichilia connaroides* (Wight & Arn.) Bentv.		✓	✓								
160	*Turpinia malabarica* Gamble	✓		✓								
161	*Vateria indica* L.		✓		✓	✓	✓	✓			✓	
162	*Vepris bilocularis* Engl.			✓					✓			
163	*Vitex altissima* L.f.	✓	✓	✓					✓	✓		✓

164	*Walsura trifoliolata* (A.Juss.) Harms					✓			✓		✓	
165	*Wrightia tinctoria* R.Br.											✓
166	*Xanthophyllum arnottianum* Wight		✓	✓	✓	✓	✓	✓	✓	✓		✓
167	*Zanthoxylum rhetsa* DC.								✓	✓		

6.2. Species List of 1ha plots (3 plots)

Sl.no	Species	Plot code		
		P8	P10	P11
1	*Acronychia pedunculata* (L.) Miq.			✓
2	*Actinodaphne salicina* Meisn.	✓		✓
3	*Aglaia tomentosa* Teijsm. & Binn.	✓		
4	*Agrostistachys borneensis* Becc.	✓		
5	*Albizia amara* (Roxb.) B.Boivin		✓	
6	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr.		✓	
7	*Ardisia blatteri* Gamble			✓
8	*Ardisia pauciflora* B.Heyne ex Roxb.	✓		
9	*Artocarpus heterophyllus* Lam.	✓		
10	*Bauhinia racemosa* Lam.		✓	
11	*Beilschmiedia wightii* Benth. & Hook.f.			✓
12	*Canarium strictum* Roxb.	✓		
13	*Carissa carandas* L.		✓	
14	*Celtis timorensis* Span.		✓	
15	*Chloroxylon swietenia* DC.		✓	
16	*Chukrasia tabularis* A.Juss.			✓
17	*Cinnamomum wightii* Meisn.			✓
18	*Cinnamomum cassia* (L.) J.Presl	✓		
19	*Cipadessa baccifera* (Roth) Miq.			✓
20	*Coffea arabica* L.	✓		
21	*Commiphora caudata* (Wight & Arn.) Engl.		✓	
22	*Cullenia exarillata* A.Robyns	✓		

23	*Dalbergia lanceolaria* L.f.		✓	
24	*Daphniphyllum neilgherrense* (Wight) K.Rosenthal			✓
25	*Dichrostachys cinerea* (L.) Wight & Arn.		✓	
26	*Dimocarpus longan* Lour.	✓		
27	*Diospyros ebenum* J.Koenig ex Retz.		✓	
28	*Dolichandrone arcuata* (Wight) C.B.Clarke		✓	
29	*Drypetes sepiaria* (Wight & Arn.) Pax & K.Hoffm.			✓
30	*Drypetes wightii* (Hook.f.) Pax & K.Hoffm.	✓		
31	*Drypetes venusta* (Wight) Pax & K.Hoffm.	✓		
32	*Garcinia morella* (Gaertn.) Desr.	✓		
33	*Givotia moluccana* (L.) Sreem.		✓	
34	*Grewia tiliifolia* Vahl		✓	
35	*Gyrocarpus americanus* Jacq.		✓	
36	*Hardwickia binata* Roxb.		✓	
37	*Heritiera papilio* Bedd.	✓		
38	*Holigarna nigra* Bourd.	✓		
39	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken			✓
40	*Ilex walkeri* Wight & Gardner ex Thwaites			✓
41	*Isonandra lanceolata* Wight	✓		
42	*Isonandra perrottetiana* A.DC.			✓
43	*Ixora brachiata* Roxb.			✓
44	*Ixora pavetta* Andr.		✓	
45	*Knema attenuata* Warb.	✓		
46	*Lannea coromandelica* (Houtt.) Merr.		✓	
47	*Lasianthus acuminatus* Wight			✓
48	*Lasianthus jackianus* Wight	✓		

49	*Leea indica* (Burm. f.) Merr.	✓		
50	*Litsea stocksii* Hook.f.	✓		
51	*Litsea wightiana* (Nees) Hook. f.			✓
52	*Macaranga peltata* (Roxb.) Müll.Arg.			✓
53	*Mastixia arborea* (Wight) C.B.Clarke			✓
54	*Meiogyne pannosa* (Dalzell) J. Sinclair	✓		
55	*Memecylon talbotianum* D.Brandis	✓		
56	*Mesua ferrea* L.	✓		
57	*Myristica dactyloides* Gaertn.	✓		
58	*Neolitsea fischeri* Gamble			✓
59	*Neolitsea scrobiculata* Gamble			✓
60	*Nothopegia beddomei* Gamble			✓
61	*Palaquium ellipticum* (Dalzell) Baill.	✓		
62	*Pavetta indica* L.		✓	
63	*Persea macrantha* (Nees) Kosterm.			✓
64	*Phyllanthus emblica* L.		✓	
65	*Polyalthia coffeoides* (Thwaites) Hook.f. & Thomson	✓		
66	*Premna tomentosa* Willd.		✓	
67	*Psychotria nilgiriensis* Deb & M.G.Gangop.			✓
68	*Psydrax umbellata* (Wight) Bridson		✓	
69	*Pterocarpus marsupium* Roxb.		✓	
70	*Rapanea wightiana* (Wall. ex A. DC.) Mez			✓
71	*Saprosma foetens* (Wight) K.Schum.			✓
72	*Strychnos potatorum* L.f.		✓	
73	*Symplocos cochinchinensis* (Lour.) S. Moore			✓
74	*Syzygium densiflorum* Wall. ex Wight & Arn.			✓
75	*Syzygium gardneri* Thwaites			✓
76	*Syzygium laetum* (Buch.-Ham.)	✓		

	Gandhi			
77	*Tarenna monosperma* (Wight & Arn.) D.C.S.Raj			✓
78	*Tectona grandis* L.f.		✓	
79	*Wrightia tinctoria* R.Br.		✓	
80	*Ziziphus oenopolia* (L.) Mill.		✓	

6.3. List of Species missed from first survey

Sl.no	Species	Plot code										
		P1	P2	P3	P4	P5	P6	P7	P9	P12	P13	P14
1	*Aglaia lawii* (Wight) C.J.Saldanha											✓
2	*Antidesma alexiteria* L.				✓							
3	*Aporosa cardiosperma* (Gaertn.) Merr.						✓					
4	*Artocarpus hirsutus* Lam.											✓
5	*Bischofia javanica* Blume		✓									
6	*Calophyllum polyanthum* Wall. ex Planch. & Triana							✓				
7	*Canarium strictum* Roxb.				✓							
8	*Croton malabaricus* Bedd.								✓			
9	*Cyathocalyx zeylanicus* Champ. ex Hook.f. & Thomson						✓					
10	*Dimorphocalyx beddomei* (Bent h.) Airy Shaw				✓							
11	*Diospyros oocarpa* Thwaites										✓	
12	*Ficus nervosa* B.Heyne ex Roth					✓						
13	*Flacourtia montana* J.Graham				✓					✓		
14	*Gmelina arborea* Roxb.									✓		
15	*Ixora nigricans* R.Br. ex Wight & Arn.									✓		
16	*Macaranga peltata* (Roxb.) Müll.Arg.				✓	✓			✓			
17	*Mallotus philippensis* (Lam.) Müll.Arg.	✓										
18	*Meiogyne pannosa* (Dalzell) J. Sinclair		✓									
19	*Meiogyne ramarowii* (Dunn) Gandhi		✓									
20	*Melia azedarach* L.										✓	
21	*Mimusops elengi* L.									✓		
22	*Nothapodytes nimmoniana* (J.Gr					✓						

	aham) Mabb.											
23	*Nothopegia travancorica* Bedd. ex Hook.f.									✓	✓	
24	*Pajanelia longifolia* (Willd.) K.Schum.		✓									
25	*Phyllanthus emblica* L.											✓
26	*Pterospermum rubiginosum* B.H eyne ex Wall.			✓								
27	*Sapindus trifoliatus* L.										✓	
28	*Schleichera oleosa* (Lour.) Merr.									✓		
29	*Scolopia crenata* Clos				✓							
30	*Sterculia guttata* Roxb. ex G.Don					✓						
31	*Symplocos racemosa* Roxb.		✓									
32	*Tabernaemontana alternifolia* L.		✓									
33	*Toona ciliata* M.Roem.							✓				
34	*Trema orientalis* (L.) Blume										✓	
35	*Xanthophyllum arnottianum* Wig ht										✓	

6.4. List of species added in second survey

Sl.no	Species	Plot code			
		P12	P2	P4	P7
1	*Aphanamixis polystachya* (Wall.) R.Parker	✓			
2	*Baccaurea courtallensis* (Wight) Müll.Arg.				✓
3	*Ixora nigricans* R.Br. ex Wight & Arn.			✓	
4	*Leea indica* (Burm. f.) Merr.				✓
5	*Lepisanthes erecta* (Thwaites) Leenh.				✓
6	*Macaranga peltata* (Roxb.) Müll.Arg.		✓		
7	*Paracroton pendulus* (Hassk.) Miq.				✓
8	*Vateria indica* L.				✓

6.5. List of IUCN categorized species

Sl.no	Species	IUCN Status					Plots in which they present													
		CR	EN	VU	NT	LC	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
1	*Actinodaphne salicina* Meisn.		✓											✓			✓			
2	*Aglaia lawii* (Wight) C.J.Saldanha					✓		✓	✓	✓	✓		✓		✓					
3	*Aglaia tomentosa* Teijsm. & Binn.					✓							✓	✓						
4	*Alstonia scholaris* (L.) R. Br.					✓	✓		✓								✓	✓		✓
5	*Aphanamixis polystachya* (Wall.) R.Parker					✓									✓			✓		
6	*Ardisia blatteri* Gamble		✓														✓			
7	*Caryota urens* L.					✓			✓		✓	✓			✓					
8	*Chloroxylon swietenia* DC.			✓												✓				
9	*Chukrasia tabularis* A.Juss.					✓											✓			
10	*Cinnamomum wightii* Meisn.		✓														✓			
11	*Cynometra travancorica* Bedd.		✓												✓					
12	*Dalbergia lanceolaria* L.f.					✓										✓				
13	*Dichrostachys cinerea* (L.) Wight & Arn.					✓										✓				
P8	*Dimocarpus longan* Lour.				✓			✓		✓	✓		✓	✓	✓		✓	✓		✓
15	*Dimorphocalyx beddomei* (Benth.) Airy Shaw		✓												✓					
16	*Diospyros candolleana* Wight			✓				✓	✓			✓			✓		✓			
17	*Diospyros crumenata* Thwaites		✓								✓						✓			

18	*Diospyros paniculata* Dalzell			✓					✓		✓	✓			✓		✓	✓		✓
19	*Dipterocarpus indicus* Bedd.		✓								✓									
20	*Drypetes wightii* (Hook.f.) Pax & K.Hoffm.			✓										✓						
21	*Dysoxylum malabaricum* Bedd. ex C.DC.		✓					✓	✓								✓	✓		✓
22	*Hopea parviflora* Bedd.		✓				✓								✓		✓			✓
23	*Hopea ponga* (Dennst.) Mabb.		✓								✓									
24	*Hopea racophloea* Dyer		✓									✓					✓			
25	*Kingiodendron pinnatum* (DC.) Harms		✓					✓		✓	✓	✓			✓		✓	✓		
26	*Knema attenuata* Warb.					✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓
27	*Litsea nigrescens* Gamble		✓												✓					
28	*Lophopetalum wightianum* Arn.					✓	✓													
29	*Mastixia arborea* (Wight) C.B.Clarke					✓							✓				✓			
30	*Myristica malabarica* Lam.			✓			✓	✓	✓	✓	✓	✓			✓		✓			
31	*Neolitsea fischeri* Gamble			✓													✓			
32	*Psychotria macrocarpa* Hook.f.		✓									✓								
33	*Pterocarpus marsupium* Roxb.			✓												✓				
34	*Pterospermum reticulatum* Wight & Arn.			✓			✓								✓					✓
35	*Syzygium densiflorum* Wall. ex Wight & Arn.			✓								✓					✓			
36	*Tabernaemontana alternifolia* L.				✓				✓								✓			✓

37	*Tarenna monosperma* (Wight & Arn.) D.C.S.Raj		✓														✓			
38	*Tetrameles nudiflora* R. Br.					✓							✓		✓			✓		✓
39	*Toona ciliata* M.Roem.					✓		✓	✓		✓	✓					✓	✓		
40	*Vateria indica* L.	✓						✓		✓	✓	✓	✓				✓			
41	*Wrightia tinctoria* R.Br.					✓										✓				✓