

## Tree Population Dynamics in a Low Elevation Evergreen Forest in the Western Ghats of Kerala, India

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### ABSTRACT

Forest dynamics were studied for trees  $\geq 10.1$  cm gbh in a 0.5 ha plot in a low elevation evergreen forest at Sivapuram in the Western Ghats of Kerala, India. The plot, established and inventoried for trees in 2000 and resurveyed in 2010, represented a freshwater swamp forest dominated by *Knema attenuata*, *Myristica malabarica*, *Holigarna arnottiana*, *Polyalthia fragrans* and *Hopea parviflora* during both censuses. During the 10-year interval the tree species composition did not change and the overall changes in total stem density and basal area were small. Girth class distribution of trees showed a negative exponential pattern in both 2000 and 2010 and did not differ significantly between the two study periods. The arboreal community of the sampled plot found to be stable and dynamic as indicated by the mortality, recruitment rates, and consequently those of half-life and duplication period, are approximately balanced. The mortality of stem was size-dependent with higher values for density and basal area mortality rate in larger stems  $\geq 120.1$  cm gbh due to natural death of old trees. Density and basal area recruitment were comparatively high in girth classes 10.1-30.0 cm and 30.1-60.0 cm respectively. These attributes suggest that the study area has remained in good condition since monitoring began in 2000.

Key Words: Forest Dynamics; Freshwater Swamp Forest; Permanent Plot; Tree Basal Area; Tree Density; Tropical Forest

### INTRODUCTION

Many areas in the tropics are undergoing rapid and wide ranging changes in land cover. Among these changes, tropical forest clearing is dramatic. Most of the extinctions of tropical forest can be attributed to pressure of poverty and population growth (Myers 1988). Lack of technical and scientific infrastructure makes efforts of sustainable management of these natural resources extremely difficult (Stork 2010). It is also clear that better knowledge on biodiversity, growing stock, productivity and dynamics of tropical forests is the prerequisite to identify conservation strategies and reliable alternatives to get rid of uncontrolled and probably dangerous development activities (Laurance and Bierregaard 1997). In this context, Hubbell and Foster (1992) advocated for establishment permanent plots in natural forests with an aim to document and monitor plant diversity and to obtain long-term data on ecosystem structures, dynamics

and properties. Some of the long-term studies of tree population dynamics in permanent plots revealed that that in relatively undisturbed forests the community maintains stability in spite of fluctuations in the mortality and recruitment rates of some populations (Phillips 1996, Sheil et al. 2000, Kohyama et al. 2001). Long-term studies in permanent plots established in disturbed forests also helped to evaluate the changes in tree species diversity, composition and dynamics in relation to the degree and frequency of disturbance (Nebel et al. 2001, Coates 2002, Fashing et al. 2004). Observations of vegetation dynamics in permanent plots not only provide insight into several ecological patterns that are not predicted but also scientific base for evaluating existing management approaches and their impacts on forest ecosystem (Sheil et al. 2000).

The Western Ghats in India is one of the megabiodiversity centres of the world. In tune with the global biodiversity conservation efforts, the need of protection

and sustainable management of forests of the Western Ghats have already been highlighted (Collins et al. 1991). In the Western Ghats, forest types are diverse and each forest type is represented by different of plant association and stocking levels (Pascal 1988). Yet, long-term studies based on permanent plots are only few (Rai 1981, Pascal and Pelissier 1996, Sukumar et al. 1998, Ayyappan and Parthasarathy 1999, Baithalu et al. 2012). In addition, only in a few permanent plots, forest dynamics have been studied in terms of tree growth, mortality and recruitment rates. In fact, all the forest dynamics studies in India have been made in deciduous forests, medium and high elevation evergreen and semi-evergreen forests, whereas such studies are still lacking in low elevation evergreen forests. The aim of this paper is to present tree population changes in a tropical low elevation evergreen forest in the Western Ghats of India, 10 years after the original inventory.

## STUDY AREA

Research was conducted in a low elevation evergreen forest at Sivapruam (11° 55' 09" N and 75° 35' 44" E; 76 m above mean sea level) in the State of Kerala. The climate is typically monsoonal with an annual average rainfall of 2600 mm, most of which (77%) falls during the southwest monsoon i.e., June to September. The rainfall during the retreating monsoon (October to December) is about 8% of the total. January to March is relatively dry. The pre-monsoon fall during April-May may be about 15% of the total. Mean annual maximum and minimum temperature is 37.3 °C and 17 °C respectively. Soil is red lateritic (oxisol), acidic (pH 5.8 to 6.0) with high organic content. The vegetation represents a swamp forest, inundated with fresh water during monsoon (June to September).

## METHODOLOGY

During 2000, the Kerala Forest Research Institute established a 0.5 ha permanent plot in the Sivapuram forest. The plot was subdivided into fifty 10 x 10 m quadrats and all trees  $\geq 10.1$  cm gbh (measured with tape at 1.37 m above ground) were tagged with numbered aluminium labels. Tags were fixed above 1.37 m level to avoid interference with gbh measurement. Each tree was identified, its number and gbh recorded. For the trees with large buttress, girth was measured just above the

level of buttress. In case of trees with multiple stems, each stem was measured separately. The data of the first inventory were analysed in accordance with published procedures (Kershaw 1973). The density, basal area and frequency of distribution trees in the plot were analysed for relative density, relative dominance and relative frequency respectively. The sum of relative density, relative dominance and relative frequency represented Importance Value Index (IVI) of various species. Shannon index of general diversity and Simpson's index of dominance were calculated following Margalef (1969) and Simpson (1949) respectively. The results of this inventory were published by Chandrashekara and Jayaraman (2002).

In second enumeration in 2010, newly recruited stems ( $\geq 10.1$  cm gbh) and dead stems within the plot were recorded. The similar trunk measurement was conducted for all surviving and recruited trees. Thus, the variables of the community dynamics were obtained for the period between 2000 and 2010. The variables included the number and basal area of the individuals in the first sampling, dead individuals, recruited individuals, individual survived between two samplings and individuals in the second sampling. These variables were used to calculate mortality and half-life, recruitment and time of duplication, replacement and stability for stem and basal area by adopting the standard procedures (Swaine et al. 1987, Korning and Balslev 1994, Sheil and May 1996).

$$\text{Mortality rate (\% year}^{-1}\text{)} = [\ln (N_b/N_s)] \times 100/t$$

$$\text{Recruitment rate (\% year}^{-1}\text{)} = [\ln (N_e/N_s)] \times 100/t$$

$$\text{Half-life (year)} = \ln (0.5)/(\text{annual mortality rate})$$

$$\text{Doubling time (year)} =$$

$$\ln (2)/\ln (1 + \text{annual recruitment rate})$$

$$\text{Replacement time (year)} =$$

$$(\text{Half-life} + \text{Duplication time})/2$$

$$\text{Stability (year)} = \text{Half-life} - \text{Doubling time}$$

where:  $N_b$  = number of individuals in the first sampling;  $N_s$  = number of individuals survived between two samplings;  $N_e$  = Number of individuals in the second sampling;  $t$  = time interval (years) between the two samplings.

Above mentioned forest dynamics measures were also calculated for basal area by replacing stem values with basal area values. To test the relationship between the

mortality rates and the individual size, estimate of the dynamic properties were made for different girth classes, with intervals of 30 cm (from 10.1 to 180.0 cm) and then for all individuals >180.1 cm.

## RESULTS

A description of tree population in a 0.5 ha plot established in 2000, and remeasured in 2010 is presented in Table 1. All 29 species recorded during the first census (2000) were present during the second census (2010). *Knema attenuata*, *Myristica malabarica*, *Holigarna*

*arnottiana*, *Polyalthia fragrans* and *Hopea parviflora* were the top five species in terms of IVI during both censuses. Five species (17%) of the 29 species identified in 2000 decreased in abundance, seven (24.1%) increased and 17 (59%) remained at nearly the same abundance over the next ten years. Among the five dominant species *Knema attenuata*, *Myristica malabarica* and *Hopea parviflora* showed decrease in their stem density.

In the sample plot, a total of 403 trees (gbh  $\geq$ 10.1 cm) were recorded in the first sampling and the value reduced moderately to 399 individuals during the second sampling (Table 2). Similarly, basal area also decreased

Table 1. Changes in number of stems (individuals 0.5 ha<sup>-1</sup>), basal area (m<sup>2</sup> 0.5 ha<sup>-1</sup>) and species importance value index (IVI) in 10 years (2000-2010) in a low elevation evergreen forest at Sivapuram, Kerala, India. Species are arranged in the decreasing order of IVI during 2000.

Species	Family	Number of stems (No. 0.5 ha <sup>-1</sup> )		Basal area (m <sup>2</sup> 0.5 ha <sup>-1</sup> )		Importance Value Index	
		2000	2010	2000	2010	2000	2010
<i>Knema attenuata</i> (Wall. ex Hk.f. &Thoms.) Warb.	Myristicaceae	139	134	4.342	4.051	80.45	80.48
<i>Myristica malabarica</i> Lamk.	Myristicaceae	94	85	3.789	3.289	58.01	59.51
<i>Holigarna arnottiana</i> Hk. f.	Anacardiaceae	41	48	2.185	2.473	34.49	38.25
<i>Polyalthia fragrans</i> (Dalz.) Bedd.	Annonaceae	12	13	0.765	0.784	12.47	14.06
<i>Hopea parviflora</i> Bedd.	Dipterocarpaceae	10	8	0.892	0.704	12.21	9.84
<i>Alstonia scholaris</i> (L.) R.Br.	Apocynaceae	14	14	0.351	0.351	10.55	9.64
<i>Artocarpus hirsutus</i> Lamk.	Moraceae	9	9	0.727	0.727	10.50	10.72
<i>Diospyros bourdillonii</i> Brand.	Ebenaceae	16	18	0.099	0.106	9.57	9.13
<i>Elaeocarpus tuberculatus</i> Roxb.	Ealeocarpaceae	7	4	0.652	0.373	8.56	6.28
<i>Hydnocarpus pentandra</i> (Buch.- Ham.) Oken	Flocourtiaceae	5	5	0.628	0.628	7.42	7.13
<i>Aglaia elaeagnoidea</i> (Juss.) Benth.	Meliaceae	8	5	0.259	0.162	7.01	4.73
<i>Myristica dactyloides</i> Lamk.	Myristicaceae	9	12	0.144	0.183	6.09	6.62
<i>Syzygium zeylanicum</i> (L.) DC.	Myrtaceae	3	3	0.586	0.586	5.67	5.37
<i>Ixora nigricans</i> Gamble	Rubiaceae	4	4	0.346	0.346	5.02	4.13
<i>Cinnamomum malabatum</i> (Burm.f.) Bl.	Lauraceae	4	4	0.280	0.280	4.64	4.72
<i>Aporosa lindleyana</i> ((Wt.) Baill.	Euphorbiaceae	5	5	0.087	0.087	4.26	3.77
<i>Symplocos racemosa</i> var. <i>racemosa</i> Roxb.	Symplocaceae	4	6	0.200	0.279	4.17	5.71
<i>Prunus ceylanica</i> (Wt.) Miq.	Rosaceae	3	3	0.166	0.160	3.22	3.23
<i>Ficus nervosa</i> Heyne ex Roth	Moraceae	3	3	0.062	0.062	2.61	2.12
<i>Turpinia malabarica</i> Gamble	Staphyleaceae	2	2	0.167	0.167	2.48	2.53
<i>Diospyros oocarpa</i> Thw.	Ebenaceae	2	2	0.127	0.127	2.24	2.28
<i>Actinodaphne bourdillonii</i> Gamble	Lauraceae	2	2	0.035	0.035	1.71	1.71
<i>Persea macrantha</i> (Nees) Kosterm.	Lauraceae	1	1	0.096	0.096	1.31	1.34
<i>Mangifera indica</i> L.	Anacardiaceae	1	1	0.067	0.067	1.14	1.16
<i>Pterospermum reticulatum</i> Wt. &Arn.	Sterculiaceae	1	2	0.045	0.000	1.01	1.49
<i>Vitex altissima</i> L.	Verbenaceae	1	3	0.021	0.000	0.87	1.74
<i>Sterculia guttata</i> Roxb.	Sterculiaceae	1	1	0.009	0.009	0.80	0.80
<i>Mallotus philippensis</i> (Lamk.) M.-A.	Euphorbiaceae	1	1	0.005	0.005	0.78	0.78
<i>Lophopetalum wightianum</i> Arn.	Celastraceae	1	1	0.002	0.002	0.76	0.75

moderately. Increase in species diversity value ( $H=2.237$  in 2000 and  $H=2.283$  in 2010) and decrease species dominance value ( $C=0.1906$  in 2000 and  $C=0.1801$  in 2010) over ten-year period were also moderate.

In the period between the two samplings there was a 31.8% death toll among the 403 individuals marked initially, with an annual mortality rate of 3.82% (Table 2). The loss of basal area between the two samplings was 29.4%, with an annual reduction in basal area of 3.27%.

The tree community showed a recruitment rate of 31.1% of the total number of individuals in the second sampling. The annual recruitment rate obtained for this study was 3.72%. During the investigated period, the recruited individuals contributed a total basal area of 4.04 m<sup>2</sup>, while the total basal area of survived individuals was 12.35 m<sup>2</sup>. A fraction (2.02%) of the total basal area of surviving individuals was due to increment in their basal area over 10-year period.

In terms of number of individuals, the annual recruitment was almost equal to the annual mortality observed in the community (Table 2). Consequently, the half-life and doubling periods were very similar. The replacement time and stability were higher for basal area than for the number of individuals.

Table 2. Ten-year changes in number of individuals and basal area of the tree community (>30.1 cm gbh) in a low elevation evergreen forest at Sivapuram, Kerala, India.

Parameters	Tree stems [No. (0.5 ha) <sup>-1</sup> ]	Basal area [m <sup>2</sup> (0.5 ha) <sup>-1</sup> ]
Sampling time 1 (2000)	403	17.53
Sampling time 2 (2010)	399	16.14
Death during 2000-2010	128	5.03
Surviving/increase after 10 years	275	12.10
Recruitment/increase during 10 years	124	4.04
Stem mortality rate, % yr <sup>-1</sup>	3.82	
Stem recruitment rate, % yr <sup>-1</sup>	3.72	
Stem half-life, years	18.17	
Stem duplication time, years	18.97	
Stem replacement value, years	18.55	
Stem stability value, years	0.83	
Basal area mortality rate, % yr <sup>-1</sup>	3.27	
Basal area recruitment rate, % yr <sup>-1</sup>	2.83	
Basal area half-life, years	21.18	
Basal area duplication time, years	24.85	
Basal area replacement value, years	23.01	
Basal area stability value, years	3.67	

The girth class distribution of stems, both in 2000 and 2010, exhibited a roughly negative exponential trend (Table 3). Very small stem (10.1-30.0 cm) accounted for 27.8% of all stems in 2000, but 33.9% in 2010. Decrease in basal area of stems of girth class 30.1 to 90.0 cm gbh was also noticed.

Absolute mortality and recruitment varied among size classes with stems of 30.1 to 60 cm gbh having higher mortality and stems of 10.1 to 30.0 cm gbh showed higher recruitment (Table 3). In general, the value of absolute recruitment of stems was lower than those for absolute mortality in girth >60.1 cm.

The mortality and the recruitment rates were strongly influenced by the girth classes. Trees with girth class 30.1 to 60.0 cm and  $\geq 120.1$  cm gbh showed large mortality rate. The mortality rate for basal area was also high for girth class  $\geq 120.1$  cm gbh (Table 3).

The recruitment rate for density was low for trees with gbh ranging from 30.1-120.0 cm than for trees of smaller (10.1-30.0 gbh) and larger girth classes ( $\geq 120.1$  cm gbh) (Table 3). The recruitment rate for basal area was high for smaller trees (10.1-30.0 gbh) and medium-sized trees (90.1 to 150.1 cm gbh).

## DISCUSSION

One of the characteristic features of the humid tropical forest is its high species-richness (Parsons and Cameron 1974). However, due to inherent variations in parameters such as altitude, geology, hydrology, environmental fluctuations, vegetation composition, a broad range in number of species in tropical forests can be seen (Whitmore 1984, Pascal 1988). For instance, considering solely the species of trees >30 cm gbh, Singh et al. (1981) recorded 84 species from 0.4 ha plot in a wet evergreen forest in the Kerala part of the Western Ghats of India. In the present study, only 29 species were recorded from 0.5 ha plot. Occurrence of comparatively less number of tree species in the study area could be due to the fact that the plot gets inundated seasonally and thus may be a suitable habitat only for a few species that can establish and survive in swamps.

The over-dominance of *Knema attenuata*, *Myristica malabarica*, *Holigarna arnottiana* and *Polyalthia fragrans* can be attributed for their 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 *Knema attenuata* and *Myristica malabarica*. In the case of swamp growing

Table 3. Number of individuals, basal area, stem and basal area recruitment and mortality rates in different girth classes in a low elevation evergreen forest at Sivapuram, Kerala, India.

Parameters	Girth Classes, cm						
	10.1- 30.0	30.1-60.0	60.1-90.0	90.1-120.0	120.1-150.0	150.1-180.0	>180.1
Number of individuals (0.5 ha <sup>-1</sup> ) in 2000	112	118	81	61	20	7	4
Number of individuals (0.5 ha <sup>-1</sup> ) in 2010	135	108	75	51	21	6	3
Recruitment of stems (0.5 ha <sup>-1</sup> )	54	32	18	8	9	2	1
Stem recruitment rate (% year <sup>-1</sup> )	5.11	3.51	2.74	1.71	5.6	4.05	4.05
Mortality of stems (0.5 ha <sup>-1</sup> )	31	42	24	18	8	3	2
Stem mortality rate (% year <sup>-1</sup> )	3.24	4.4	3.51	3.5	5.11	5.6	6.93
Basal area (m <sup>2</sup> 0.5 ha) in 2000	0.36	1.92	3.68	5.45	2.95	1.54	1.23
Basal area (m <sup>2</sup> 0.5 ha <sup>-1</sup> ) in 2010	0.39	1.55	3.00	6.55	2.68	1.16	0.81
Basal area recruitment rate (% year <sup>-1</sup> )	5.11	2.63	1.97	4.94	6.08	2.51	1.18
Basal area mortality rate (% year <sup>-1</sup> )	3.79	2.32	1.95	3.22	3.99	5.84	7.71

*Holigarna arnottiana* and *Polyalthia fragrans*, breathing roots in the form of loops studded with lenticels protruded into the air from the flooded substratum are common.

Since monitoring began in 2010, the changes observed in the study area in relation to vegetation structure, composition and species diversity were low compared with values reported for several other tropical forests (Lang & Knight 1983, Korning and Balslev 1994, Oliviera-Filho et al. 1997). In terms of species composition, the study area is stable with same 29 species were recorded during both during censuses. Besides, all five dominant species in 2000 remained dominant in 2010. Overall changes in total stem density and basal area were small, with mortality more or less balancing recruitment (stem mortality: 3.82% yr<sup>-1</sup>; stem recruitment: 3.72% yr<sup>-1</sup>; basal area mortality: 3.27 % yr<sup>-1</sup>; basal area recruitment: 2.83 % yr<sup>-1</sup>). Moreover, the values for annual mortality and recruitment rates of the plot were high compared to those obtained for other tropical lowland forests (Swaine et al. 1987, Phillips and Gentry 1994, Nebel et al. 2001). Consequently the stand half-life and doubling times for the plot was also low indicating that the forest patch is dynamic. The forest community in Sivapuram is also stable in relation to forest structure as indicated by the low stability value (0.83). It may be pointed out here that data obtained for mortality and recruitment rates based on stem density and basal area need careful interpretation as numerically similar figures may be obtained for both early and late successional (primary forest) stages (Lieberman et al. 1990). With this background, assessment of forest

conditions should be based on several other parameters. The size class distribution of tree community is one such 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 evergreen forests shows a negative exponential distribution with a clear preponderance of stems of small girth classes. In the Sivapuram forest too, the girth class distribution took the shape of an inverse J-curve, characteristic to a typical relatively undisturbed evergreen forest. Moreover, girth class distribution did not differ significantly between the two study periods, suggesting that the tree community has been structurally stable over the course of the study.

In tropical evergreen forests, the contribution of successional tree species to the total species importance value index is less in a relatively undisturbed stand than in a disturbed stand (Denslow 1980). In the study area at Sivapuram, successional tree species were represented by *Actinodaphne bourdillonii*, *Alstonia scholaris*, *Mallotus philippensis*, *Pterospermum reticulatum* and *Vitex altissima* and their total contribution to the species IVI was 14.92 % and 15.36% respectively during 2000 and 2010. Occurrence of successional species in the study area is an indication of natural gap related regeneration as the forest showed no overt signs of human disturbance and between two censuses, all trees died of natural causes.

In the present study, as also observed by Runkle (2000) and Miura et al. (2001), a size-dependent mortality was observed. Higher values for density and basal area mortality rates in larger stems ( $\geq 120.1$  cm)

could be due to natural death of old trees. Higher stem mortality among individuals belonging to the girth class 30.1 to 60.0 cm could be due to two reasons namely senescence of understorey tree species, which have short lifespan and breakage of trees of small stature by other trees. Comparatively high density recruitment for lower girth class (10.1- 30.0 cm) and basal area recruitment in girth class 30.1 -60.0 cm indicate the better regeneration and stability of the study area.

## CONCLUSION

Tree population changes 10 year after the original inventory in the lowland evergreen forest at Sivapuram revealed an insignificant change in species richness, density and basal area. Despite the fact that being located amidst to a rural landscape, the plot remained relatively undisturbed with no overt sign of human disturbance. The conservation measures, including the establishment of forest station, involvement of local community for patrolling, applied by the Kerala Forest Department appeared to be effective. Incidentally the study area is located adjacent to a temple (although not considered as a sacred grove). The proximity to the temple may also be contributing to keep the forest undisturbed.

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