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REGENERATION STUDY OF SELECTED *TERMINALIA*S IN KERALA

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(Final Report of project KFRI 471/2005)

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Project Proposal

Project No. : KFRI 471/2005

Title : Regeneration study of selected *Terminalia*s in Kerala

Investigator : PK Chandrasekhara Pillai

UM Chandrashekara

Objectives

1. To survey and analyze the regeneration status of selected species of *Terminalia* (*T. crenulata* Roth, *T. paniculata* Roth and *T. travancorensis* Wt. & Arn.) in Kerala.
2. To study phenology, seed characteristics and germination pattern of the species.
3. To develop a package of nursery practices of the species.

Duration : April 2005 – March 2009

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Contents

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Absrtact

Successful management of natural forests depends on good natural regeneration of valuable species. The present investigation was conducted in the Kerala part of Western Ghats from Northern to Southern Forest Circles representing all the Ranges belonging to each Forest Division. The study envisaged to assess demographic details of *Terminalia crenulata*, *T. paniculata, T. travnacorensis* and their regeneration status in natural populations. *T. crenulata* and *T. paniculata* are mainly confined to moist deciduous forests. *T. travacorensis*, a large tree endemic to the Western Ghats, occurs in low-level evergreen forests of Kerala. These species are important components of our natural forest ecosystems.

A total of 218 plots were enumerated (51.7 ha) throughout Kerala. Seeds of *T. crenulata*, *T. paniculata* and *T. travancorensis* were subjected to viability test and pre-sowing treatments to enhance germination under laboratory condition. A trial for vegetative propagation of the species was also carried out. Trees of *T. paniculata* were observed in 168 plots, *T. crenulata* in 101 plots and *T. travancorensis* in 5 plots with a density (trees ha-^{1}) of 67.14, 19.01 and 0.46. Frequency, basal area and importance value index (IVI) of the species were 0.78, 0.47, 0.02; 497.1 m^2, 179.9 m^2, 13.1 m^2; 54.118, 19.031, 0.996 respectively. About 250 species were enumerated from the study sites and *X. xylocarpa* was the major associate species with a density, frequency, basal area and IVI of 28.94, 0.43, 158.6 m^2, and 21.001, respectively. Overall species richnes (R=26.93) and diversity (H=3.71) of the study sites showed a high value. Generally, density of *T. paniculata* was higher than that for *T. crenulata* with a significant difference between Forest Circles (*P=0.01* for *T. paniculata* and *P=0.05* for *T. crenulata*). The study indicated that *T. paniculata* is more or less stable compared to *T. crenulata*. However, occurrence of *T. travancorensis* is limited to the few localities in Kerala.

Regeneration enumeration was carried out from all the temprory plots established in each Forest Division. Generally, regeneration of *T. paniculata* was more when compared to *T. crenulata*. Regeneration in the study sites had a density of 73.58 for *T. paniculata*, 18.47 for *T. crenulata* and 0.019 for *T. travancorensis*. Of the

total regeneration of *T. paniculata*, 46% comprised unestablished seedlings (<3 cm collar girth), 24% established saplings (3-9.9 cm Gbh) and 30% advanced (poles) category (10-30 cm Gbh). Fifty-six per cent of the regeneration of *T. crenulata* comprised seedlings, 26% saplings and 18% poles. However, the regeneration of *T. travancorensis* was negligible, i.e., only a single pole of *T. travancorensis* was found from the study sites. Regeneration of *T. paniculata* and *T. crenulata* between Forest Divisions was significantly different (*P=0.01*). However, it was not in par with mature trees.

The study revealed that germination of *T. paniculata* was very low due to infertility and heavy pest infestation. With respect to *T. travancorensis*, weathering treatment of seeds was needed to get a better germination. Juvenile shoots from the established seedlings responded to rooting hormones. Optimum combination for better rooting was IBA+Kinetin at 6000 ppm.

1. Introduction

Forests are one of the most important resources for mankind. At the global level, they have important bearing on the planet's climate while at the local level they provide a variety of ecosystem services and products. Based on interpretation of satellite data of December 2006 - March 2007, forest cover in Kerala is 17,324 km^2 which is 44.58 per cent of the States geographical area. Comparison of current forest cover with previous assessment (satellite data of December 2004 - February 2005) shows a gain of 40 km^2 forest cover. The reason for this increase is the change in the area of trees outside forests (TOF). Of this, 18.14% is tropical moist deciduous forests (FSI, 2009). Tropical deciduous forests assume unusual significance for conservation since they are the most used and threatened ecosystems, especially in India.

Replacement of older trees in a forest by younger ones is an important process in natural forest maturation. Sustained timber yield and productivity from a forest largely depends on well-distributed age classes. A sustained yield forest can be even-aged, uneven-aged or a combination of both. Studies related to this field will contribute in planning, conservation and decision making in natural forest resource management. Natural regeneration is important as it addresses mainstream biodiversity concerns (Reddy and Ugle, 2008). Demographic assessment of regeneration of a forest type is useful to identify the constraints affecting natural regeneration.

According to Reddy and Ugle (2008), poor representation of saplings and poles in the moist deciduous forests in southwest India shows that anthropogenic constraints should be reduced to enhance adequate replacement of older trees. About 10% of canopy gap should be retained in these forests either by autogenic or allogenic processes to increase the survival and growth of commercially important tree species. Sustained management of natural forest depends on their ability to regenerate. Unlike homogeneous plantations, management of natural forests relies largely on natural regeneration. Successful management depends on good natural regeneration of valuable species. However, studies to understand the regeneration patterns of tropical trees are scanty. In this context, the present study

was conducted to assess demographic details of selected *Terminalia*s and their associate species in the forests of Kerala. In fact, the Kerala part of Western Ghats is one of the most forested tracts of southern India and the *Terminalia*s are widely distributed in these forests. Thus, one of the specific objectives of this study was to analyse the density and distribution patterns of *Terminalia*s in the tree phase as well as to asses their regeneration status in natural forest tracts of Kerala. Such a study is important to understand the factors responsible for either sparse or dense distribution of *Terminalia*s in different forests of Kerala.

Terminalia L., a tree genus of the family Combretaceae, is an important component of moist tropical forests and is known to comprise eight species in Kerala - *T. alata* Heyne ex Roth, *T. arjuna* (Roxb. ex DC.) Wt. & Arn, *T. bellirica* (Gaertn.) Roxb., *T. chebula* Retz., *T. crenulata* Roth, *T. gella* Dalz., *T. paniculata* Roth and *T. travnacorensis* Wt. & Arn. All of them are native and economically important, in terms of wood or other produces. Earlier studies have reported that regeneration of *T. crenulata* and *T. paniculata* is heavily deficient and representation of pole crops is very poor (Swarupanandan and Sasidharan, 1992; Chandrashekara *et al*., 1998).

In the present study, detailed investigation was made on three of the species viz., *T. crenulata*, *T. paniculata* and *T. travnacorensis*. *T. crenulata*, the 'thembavu' of commercial importance, is a hardwood species yielding very durable timber useful for building construction, especially door and window frames. Bark is used in ayurvedic medicine. Although many prefer the species for door and window frames, the timber is not available in required quantity. Hence, enriching our natural moist deciduous forests with the species seems desirable. *T. paniculata*, another natural component of the MDFs, yields excellent timber for construction and general utility. Bark is used in ayurvedic medicine and tannin obtained from the bark is a substitute for wattle tannin. Most of its seeds are infertile and characteristically display very low germination rate. Apparently for these reasons, the species is too sparse in natural stands and is worth augmenting. *T. travacorensis*, a large tree endemic to the Western Ghats, occurs in low-level evergreen forests of Kerala. Its occurrence is very low and is reported from Kottayam, Peechi, Sholayar and Kariamchola of Parambikulam. It possesses

properties similar to that of *T. chebula*. No report is available on regeneration status of the species. *Terminalia*s are important components of our natural forest ecosystems. Demand for timber, raw materials for traditional medicine and their role in the maintenance of the ecosystem(s); make them very important tree resource deserving enhancement. For assisted natural regeneration or enrichment planting, suitable propagules are required. Howerver, for a number of tree speceies, suitable technques for raising propaguels are lacking; this is true even for *Terminalia*s. Thus, the present study envisages to develop suitable nursery techniques for artificial regeneration of the species.

2. Materials and Methods

Reconnaissance survey was conducted in seven Divisions of Southern Forest Circle, five Divisions of Central Forest Circle, six Divisions of Northern Forest Circle, eight Divisions of High Range Forest Circle and seven Divisions of Olavakkode Forest Circle representing all the Ranges in each Forest Division. Sites were identified in all the Sections/Stations of each Range where the species were present, and temporary plots were established to study regeneration of *T. crenulata*, *T. paniculata* and *T. travancorensis*, structural status of mother trees of the species and their associated species. A total of 218 plots of varied size (5 x 500 to 5 x 1000 m belt transect) depending on size of the area and occurrence of the species were enumerated in a total area of 51.7 ha (Fig. 1, Table 1). Height and girth at breast height of mother trees as well as associated species were measured from the belt transect. Regeneration of the three *Terminalia* species was analyzed from sub-plots of 5 x 100 m belt transect as well as from the point center plots around 10 m radius of mother trees. Regeneration of the species was classified into three girth classes, i.e., <3 cm (seedlings - un-established), 3-10 cm (saplings - established) and >10 cm (poles - advanced) (Narayanan and Swarupanandan, 1996; Menon, 2010). The un-established group was further classified into three height classes such as <50 cm height, 50-100 m and >100 cm height. Phenological observation was carried out simultaneously. Seeds were collected at different maturity periods to study the seed characteristics, viability and germination. The enumeration data were subjected to phytosociological analysis using the software 'InventNTFP' developed by KFRI (Sivaram *et al*., 2006).

Two permanent plots were established at Nilambur for monitoring regeneration dynamics of *T. paniculata* and *T. crenulata*. One plot was 100 m^2 in size with 20 m^2 sub plots and the other plot was with an area of 50 m^2 having sub plots of 10 m^2. These plots were devoid of fire and grazing. Girth and height of different categories of the regenerating trees were recorded with an interval of six months (March and September). Regeneration of different categories and its survival percentage were estimated.

Seeds of *T. crenulata*, *T. paniculata* and *T. travancorensis* were subjected to rapid viability test (cutting test) and pre-sowing treatments to enhance germination under laboratory condition. Pre-sowing treatments for *T. crenulata* were de-winging and water soaking and for *T. travancorensis*, de-pulping, weathering and splitting. Four replicates containing 100 seeds per treatment and their control were maintained in vermiculate beds in a randomized block design. The germination was recorded daily at 10.30 am. Germination percentage and germination energy were computed.

Vegetative Propagation

Juvenile cuttings were collected from the newly sprouted branches of the three *Terminalia* species and juvenile shoot cuttings from the established seedlings of *T. travancorensis* to standardize vegetative propagation methods. The tender shoots were used for uni-nodal cuttings of 5-6 cm length and 2-4 mm diameter. The cuttings were treated with Bavistin solution (1%) for 5 minutes to prevent fungal infection. Four different concentrations of rooting hormones, i.e., 5000 ppm, 6000 ppm, 7000 ppm and 8000 ppm of IBA and low kinetin combinations (99:1) were used as treatments. Freshly prepared dry mixture of rooting hormone with talcum powder was used for application. The basal portions of the cuttings were dipped in rooting mixtures of Auxin. After hormonal treatment thirty cuttings along with their control were kept in wet vermiculate rooting media filled in plastic root-trainers and placed in the mist chamber. Twenty - five days after treatment, the cuttings were carefully removed from the rooting medium and observations were recorded on the number of rooted cuttings, root number, root length, number of sprouts, sprout length, etc.

The data were analyzed and the density of mature trees as well as regeneration of *Terminalia* species were subjected to analysis of variance (ANOVA) to find out any significant difference between Forest Circles in Kerala. The data on seed germination by various pre-treatments and rooting responses of the species to different concentration of auxins were also subjected to ANOVA.

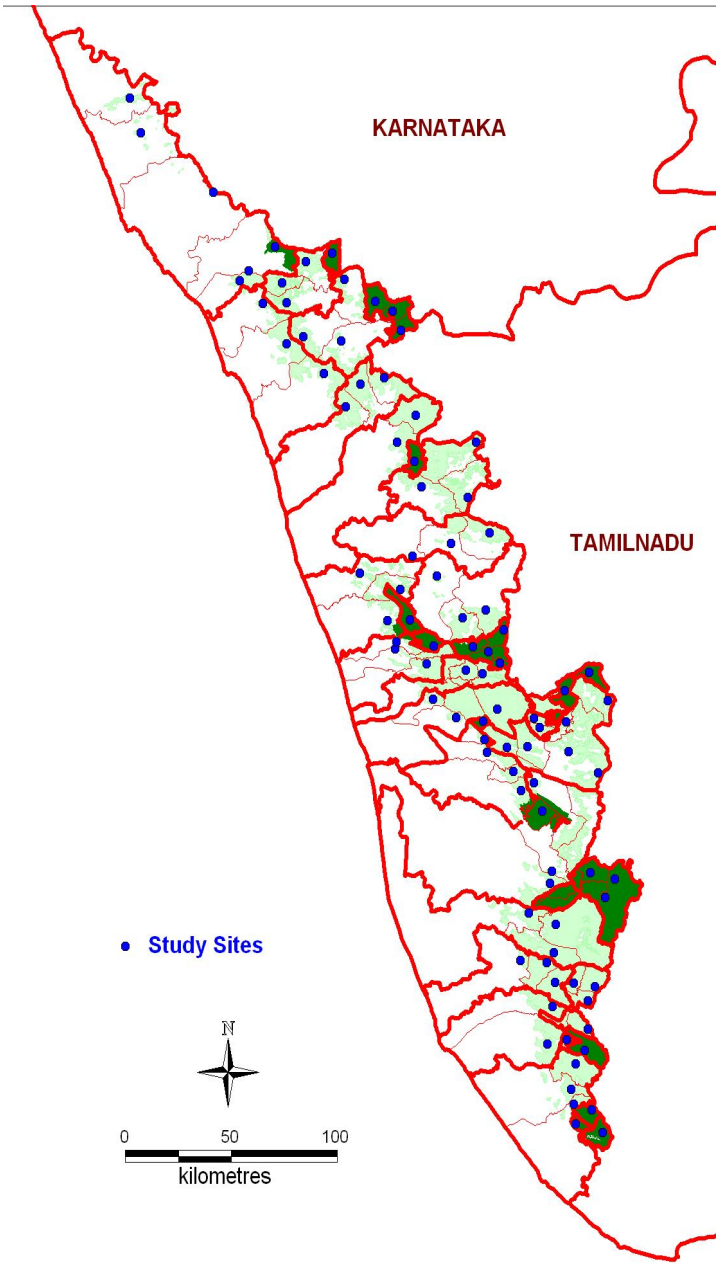

Fig. 1. Map of Kerala showing study sites in five Forest Circles

Table 1. Plots laid out for enumeration

Forest Circle	Forest division	Longitude		Latitude		No. of plots	Area (ha)
		From	To	From	To		
Northern	Kannur	75.1066	75.5425	11.4982	12.3477	15	2.60
	Kozhikkod	75.4734	75.5844	11.2955	11.3762	6	1.25
	Wayanad North	75.5021	76.0367	11.4389	11.5237	4	0.45
	Wayanad South	75.5843	76.0801	11.3307	11.4878	5	0.65
	Wayanad WLD	76.0648	76.2312	11.3794	11.5159	5	1.60
	Aralam WLD	75.4952	75.5259	11.5569	11.5713	3	0.50
	Total					**38**	**7.05**
Olavakkode	Nilambur North	76.1042	76.2550	11.0620	11.2852	10	3.40
	Nilambur South	-	-	-	-	5	1.65
	Mannarkkad	76.3051	76.4343	10.5753	11.0990	7	1.05
	Palakkad	-	-	-	-	11	3.05
	Nenmara	76.4093	76.4127	10.2725	10.2725	4	1.00
	Silent Valley NP	-	-	-	-	4	0.45
	Parambikulam WLD	76.4253	76.4981	10.2158	10.2768	6	1.95
	Total					**47**	**12.55**
Central	Chalakkudy	76.2558	76.2970	10.1789	10.2156	10	2.05
	Thrissur	-	-	-	-	7	2.00
	Malayattur	76.2924	76.3876	10.1030	10.1344	10	2.45
	Vazhachal	76.4051	76.4723	10.1749	10.1947	7	1.55
	Peechi-Vazhani WLD	76.2150	76.2261	10.1169	10.1270	5	1.35
	Total					**39**	**9.40**
High Range	Marayur SD	77.0413	77.1269	10.1492	10.1658	7	0.95
	Eravikulam NP	77.0507	77.1121	10.0930	10.1852	2	0.65
	Munnar	76.4646	77.1541	10.0115	10.0910	10	2.55
	Mankulam	76.5435	76.5588	10.0734	10.1063	3	0.80
	Thekkady WLD	77.0732	77.1597	9.3082	9.3558	9	1.40
	Idukky	76.4140	76.5703	9.4815	10.0822	10	2.05
	Kothamangalam	76.4085	76.5120	9.5481	10.0768	12	3.10
	Kottayam	76.4684	77.0232	9.2671	9.5048	6	1.50
	Total					**59**	**13.00**
Southern	Ranni	76.5286	77.0451	9.1919	9.2453	4	1.60
	Konni	-	-	-	-	3	1.05
	Achankovil	77.0646	77.0859	9.0373	9.0739	6	1.65
	Punalur	76.5782	77.0021	8.5017	9.0641	2	1.00
	Thenmala	77.0591	77.0875	8.5491	8.5731	2	1.00
	Trivandrum	77.0318	77.0907	8.3870	8.5129	8	1.20
	Trivandrum WLD	77.0591	77.1443	8.3301	8.5504	10	2.20
	Total					**35**	**9.70**
Grant total						**218**	**51.70**

3. Results and Discussion

3.1. Structural status of tree communties

Details about tree community, with special reference to Terminalias in Kerala

Terminalia species is native of the areas where the parent rock is of the crystalline series, with or without laterite. Generally, *Xylia xylocarpa*, *Grewia tiliifolia*, *Dalbergia latifolia*, *Terminalia bellirica*, *Tectona grandis*, *Lagerstroemia microcarpa*, *Dillenia pentagyna*, *Adina cordifolia*, *Pterocarpus marsupium*, etc., are the major associate species of *Terminalia paniculata* and *T. crenulata* (FRI, 1984). A basic statistics related to the tree community, with special reference to *Terminalia*s in the study sites of Kerala is given in Table 2. Density (trees ha-^{1}), frequency, basal area and importance value index (IVI) of *Terminalia* species is given in Appendix 1. A total of 259 tree species including *Terminalia* species were enumerated from the study sites.

With respect to total tree density, basal area and dominance, contribution of *T. paniculata* was more when compared to *T. crenulata*. However, contribution of *T. travancorensis* was minimal (Table 2). Detailed structural attributes of vegetation in the study sites are presented in Appendix 1. *X. xylocarpa* was recorded as maximum number of individuals among the associate species. Chandrashekara and Jayaraman (2002) also reported that *X. xylocarpa* is the dominant tree species in the moist deciduous forests of Kerala. Other major dominant tree species in the study sites were *L. microcarpa*, *T. grandis*, *P. marsupium*, *G. tiliifolia*, *T. bellerica*, etc. In the present study, *T. travancorensis* was reported only from limited localities in Kerala. Its major associate species were *Chukrasia tabularis*, *Hopea parviflora*, *Aglaia malabarica*, *Schleichera oleosa*, *Dysoxylum malabaricum*, *Palaquium ellipticum*, *Cullenia exarillata*, *Knema attenuata*, *Myristica malabarica*, etc. *T. travancorensis* occurs in low elevated evergreen forests of Kerala and the percentage of occurrence is very low (FRI, 1984). Considering these aspects it is necessary to conserve the species. The study also revealed that all the sites in Kerala had high species richness (Margalef's Index (R) - 26.93) and diversity (Shannon's Index (H) - 3.71).

Table 2. Basic statistics related to tree community, with special reference to *Terminalia*s in the study sites of Kerala

Sl. No.	Parameters		
1	Total number of plots studied		218
2	Total area (ha)		51.70
3	Total number of species		259
4	Dominant tree species		*Terminalia paniculata* *Xylia xylocarpa* *Terminalia crenulata* *Lagerstroemia microcarpa* *Tectona grandis* *Pterocarpus marsupium* *Grewia tiliifolia* *Terminalia bellerica*
5	No. of plots where trees of *Terminalias* occur	*Terminalia crenulata*	101
		Terminalia paniculata	168
		Terminalia travancorensis	5
6	Total tree density (individuals ha^{-1})		294.70 ± 4.85
7	Contribution of *Terminalias* to tree density (% of total tree density)	*Terminalia crenulata*	6.45
		Terminalia paniculata	22.78
		Terminalia travancorensis	0.16
8	Total basal area of tree community (m^2 ha^{-1})		36.6
9	Contribution of *Terminalias* to basal area of tree community (% of total basal area of tree community)	*Terminalia crenulata*	9.56
		Terminalia paniculata	26.23
		Terminalia travancorensis	0.55
10	Contribution of *Terminalias* to IVI of tree community (% of total IVI of tree community)	*Terminalia crenulata*	6.35
		Terminalia paniculata	18.05
		Terminalia travancorensis	0.33

Data obtained for each Forest Circle were analysed separately and presented below.

Northern Forest Circle: Table 3 shows the statistics related to tree community, with special reference to *Terminalia* species in the study sites of Northern Circle. *T. paniculata* was found in more plots than *T. crenulata*. However, *T. travancorensis* was not found in the study sites of Northern forest Circle. An overall structural status of tree species in Northern Forest Circle is presented in Appendix 2. Tree density, basal area and dominance (IVI) of *T. crenulata* was higher than that of *T. paniculata*; whereas, frequency was higher for *T. paniculata*. One hundred and twenty-four associate species were enumerated from the stuy sites and *X. xylocarpa* was the major one among them. Other major associate species were *O. dioica*, *L. microcarpa*, *T. bellerica*, *D. latifolia*, *G. tiliifolia*, etc. *T. crenulata* had more contribution to the total tree density, basal area and dominance in the Northern Circle as compared to *T. paniculata*. Richness index (16.07) and diversity index (3.64) showed high species richness and diversity in the Northern Circle.

Enumeration from Kannur Division of Northern Circle showed that *T. paniculata* had higher tree density and IVI (60.33/ha, 51.862) than that of *T. crenulata* (27.33/ha, 24.660). In Kozhikkode Division also *T. paniculata* had higher tree density and IVI (70.83/ha, 47.316) than *T. crenulata* (15.83/ha, 18.698). However, in the Wayand North Division, *T. crenulata* showed a higher tree density and IVI (21.67/ha, 20.418) than *T. paniculata* (8.33/ha, 15.232). Similarly, in Wayand Wildlife Division also *T. crenulata* had higher tree density and IVI (92.50/ha, 79.504) than *T. paniculata* (1.50/ha, 1.969). Only *T. paniculata* was found from Aralam Wildlife Division with a tree density of 20.95 and IVI of 26.281. Similarly, only *T. crenulata* was found from Wayand South Division with a tree density 58.67/ha and IVI 56.883. Division-wise analysis revealed that *T. paniculata* was the dominant species among *Terminalia*s in Kannur and Kozhikkode Forest Divisions. However, in Wayand North and Wayand Wildlife Divisions *T. crenulata* was dominant. Occurrence of *T. crenulata* in the study sites of Aralam Wildlife Division and *T. paniculata* in Wayand South Division is not reported. *X. xylocarpa* was the major associate species in Kannur, Aralam Wildlife and Kozhikkode Divisions, whereas *D. latifolia* was the major associate species in Wayand North Division, *O. dioica* in Wayand South Division and *G. tiliifolia* in Wayand Wild Life Division.

Table 3. Basic statistics related to tree community, with special reference to *Terminalia*s in the study sites of Northern Forest Circle

Sl. No.	Parameters		
1	Total number of plots studied		38
2	Total area (ha)		7.05
3	Total number of species		124
4	Dominant tree species		*Terminalia crenulata* *Terminalia paniculata* *Xylia xylocarpa* *Olea dioica* *Lagerstroemia microcarpa* *Terminalia bellerica* *Dalbergia latifolia* *Grewia tiliifolia*
5	No. of plots where trees of *Terminalias* occur	*Terminalia crenulata*	20
		Terminalia paniculata	22
		Terminalia travancorensis	0
6	Total tree density (individuals ha^{-1})		248.21 ± 4.90
7	Contribution of *Terminalias* to tree density (in % of total tree density)	*Terminalia crenulata*	14.55
		Terminalia paniculata	12.09
		Terminalia travancorensis	-
8	Total basal area of tree community (m^2 ha^{-1})		36.4
9	Contribution of *Terminalias* to basal area of tree community (% of total basal area of tree community)	*Terminalia crenulata*	22.20
		Terminalia paniculata	12.49
		Terminalia travancorensis	-
10	Contribution of *Terminalias* to IVI of tree community (% of total IVI of tree community)	*Terminalia crenulata*	13.49
		Terminalia paniculata	9.56
		Terminalia travancorensis	-

Olavakkode (Eastern) Forest Circle: Table 4 represents basic details related to *Terminalia* species in the study sites of Olavakkode Circle. *T. paniculata* was found in more plots than *T. crenulata* and *T. travancorensis*. Similarly, tree density, frequency, basal area and dominance were also higher for *T. paniculata* than the other two species (Appendix 3). Totally 139 species were enumerated from the study sites and *X. xylocarpa* was recorded as maximum number among the associate species (Appendix 3). Contribution of *T. paniculata* with respect to tree density, basal area and dominance to the total was more when compared to *T.*

crenulata. However, contribution of *T. travancorensis* was very minimal (Table 4). The study indicated that *T. paniculata* was dominant among *Terminalia* species in the Olavakkode Forest Circle. However, *T. travancorensis* was found only in Nenmara and Parambikulam Wildlife Divisions. Richness (17.02) and diversity (3.33) indices show high species richness and diversity in the Circle.

Tree density and IVI of *T. paniculata* (35.73/ha, 54.225) were more than that of *T. crenulata* (25.87/ha, 34.688) in Nilambur North Division. Nilambur South Division also had higher tree density and IVI for *T. paniculata* (47.47/ha, 48.601) than *T. crenulata* (42.13/ha, 47.282). With respect to Mannarkkad Division, density and IVI of *T. paniculata* (20.95/ha, 29.078) were much higher than *T. crenulata* (3.17/ha, 4.852). In Palakkad Division, *T. paniculata* had higher density and IVI (58.18/ha, 55.234) than *T. crenulata* (31.52/ha, 32.446). Tree density and IVI of *T. paniculata* (45/ha, 61.814) were much higher than *T. crenulata* (3.33/ha, 8.676) in Silent valley National Park. From the study area of Nenmara Division *T. paniculata* was found with much higher density and IVI (139/ha, 58.336) than *T. travancorensis* (11/ha, 29.718) and *T. crenulata* (11/ha, 7.011). Similarly, in Parambikulam Wildlife Division also, *T. paniculata* had much higher density and IVI (35.83/ha, 54.373) than *T. travancorensis* (2.92/ha, 6.823) and *T. crenulata* (0.83/ha, 1.576).

In general, *T. paniculata* was the dominant species in all the 7 Forest Divisions of Olavakkode Circle. The major associate species was *X. xylocarpa* in the Forest Divisions of Nilambur North, Nilambur South, Mannarkkad, Palakkad and Nenmara. But the major associate species was *Phyllanthus emblica* in the sudy sites of Silent Valley NP and *L. microcarpa* in Parambikulam Wildlife Division.

Central Forest Circle: Table 5 represents statistics of *Terminalia* species in the study sites of Central Circle. *T. paniculata* was found in more number of plots than *T. crenulata*. However, *T. travancorensis* was found only in a single plot in the Vazhachal Division. Contribution of *T. paniculata* to the total of tree density, basal area and dominance was higher than the other species (Table 5). Similarly, frequency distribution of *T. paniculata* was also more than the other *Terminalia* species (Appendix 4). *X. xylocarpa* was the major associate species in the Central

Circle. Species richness (14.58) and species diversity (3.44) were high in the Forest Circle.

Table 4. Basic statistics related to tree community, with special reference to *Terminalia*s in the study sites of Olavakkode Forest Circle

Sl. No.	Parameters		
1	Total number of plots studied		47
2	Total area (ha)		12.55
3	Total number of species		139
4	Dominant tree species		*Terminalia paniculata* *Xylia xylocarpa* *Terminalia crenulata* *Lagerstroemia microcarpa* *Grewia tiliifolia* *Schleichera oleosa* *Tectona grandis* *wrightia tinctoria*
5	No. of plots where trees of *Terminalias* occur	*Terminalia crenulata*	28
		Terminalia paniculata	41
		Terminalia travancorensis	3
6	Total tree density (individuals ha^{-1})		199.03 ± 4.81
7	Contribution of *Terminalias* to tree density (% of total tree density)	*Terminalia crenulata*	8.55
		Terminalia paniculata	19.93
		Terminalia travancorensis	0.51
8	Total basal area of tree community (m^2 ha^{-1})		39.1
9	Contribution of *Terminalias* to basal area of tree community (% of total basal area of tree community)	*Terminalia crenulata*	12.45
		Terminalia paniculata	26.65
		Terminalia travancorensis	1.66
10	Contribution of *Terminalias* to IVI of tree community (% of total IVI of tree community)	*Terminalia crenulata*	8.35
		Terminalia paniculata	17.51
		Terminalia travancorensis	0.87

Result of the Division-wise analysis showed that *T. paniculata* had higher tree density and IVI (44.80/ha, 39.625) than *T. crenulata* (18.40/ha, 19.572) in the Chalakkudy Division of Central Circle. In Malayatur Division, *T. paniculata* had much higher density and IVI (23.47/ha, 30.272) than *T. crenulata* (7.47/ha, 14.774). Tree density and IVI in study sites of Thrissur Division were higher for *T. paniculata* (68.95/ha, 51.945) than that of *T. crenulata* (17.147ha, 16.328). Enumeration from Vazhachal Division showed a higher tree density and IVI for *T. travancorensis* (3.43/ha, 7.463) than *T. paniculata* (1.71/ha, 4.727). *T. paniculata* had higher density and IVI (68/ha, 69.469) than *T. crenulata* (20.67/ha, 18.758) in Peechi-Vazhani Wildlife Division. Generally, *T. paniculata* was dominant among *Terminalia* species in the five Forest Divisions of Central Circle. Among the associate species *X. xylocarpa* was dominant except in Vazhachal Division where the dominant species was *P. ellipticum*.

Table 5. Basic statistics related to tree community, with special reference to *Terminalia*s in the study sites of Central Forest Circle

Sl. No.	Parameters		
1	Total number of plots studied		39
2	Total area (ha)		9.40
3	Total number of species		117
4	Dominant tree species		*Terminalia paniculata* *Xylia xylocarpa* *Tectona grandis* *Terminalia crenulata* *Macaranga peltata* *Grewia tiliifolia* *Lagerstroemia microcarpa* *Stereospermum colais*
5	No. of plots where trees of *Terminalias* occur	*Terminalia crenulata*	22
		Terminalia paniculata	29
		Terminalia travancorensis	1
6	Total tree density (individuals ha^{-1})		205.06 ± 4.57
7	Contribution of *Terminalias* to tree density (% of total tree density)	*Terminalia crenulata*	5.00
		Terminalia paniculata	16.20
		Terminalia travancorensis	0.20
8	Total basal area of tree community (m^2 ha^{-1})		41.8
9	Contribution of *Terminalias* to basal area of tree community (% of total basal area of tree community)	*Terminalia crenulata*	5.60
		Terminalia paniculata	18.71
		Terminalia travancorensis	0.89
10	Contribution of *Terminalias* to IVI of tree community (% of total IVI of tree community)	*Terminalia crenulata*	4.67
		Terminalia paniculata	13.18
		Terminalia travancorensis	0.41

High Range Forest Circle: Table 6 shows the statistics of *Terminalia* species in the study sites of High Range Circle. Occurrence of *T. paniculata* was reported from 71% of the total study plots, whereas in the case of *T. crenulata* it was 27%. However, presence of *T. travancorensis* was reported only from 2% of the study plots. Similarly, density, frequency, basal area and IVI were also higher for *T. paniculata* than the other species (Appendix 5). *X. xylocarpa* was the major associate species. Contribution of *T. paniculata* to the total tree density, basal area and IVI was also higher compared to other species. Richness (19.73) and diversity (3.63) indices showed high values in the High Range Circle.

Division-wise analysis showed that *T. paniculata* had higher tree density and IVI (30.67/ha, 43.757) than *T. crenulata* (19.11/ha, 25.498) in the study area of Munnar Division in High Range Circle. Density and IVI of *T. paniculata* (71.5/ha, 60.307) were higher than that of *T. crenulata* (2.50/ha, 5.384) and *T. travancorensis* (0.49/ha, 3.201) in study sites of Idukki Wildlife Division. With respect to Kothamangalam Division, tree density and IVI of *T. paniculata* (84.17/ha, 58.025) were higher than that of *T. crenulata* (21.94/ha, 15.282). From the study sites of Kottayam Division *T. paniculata* was found with higher density and IVI (145.33/ha, 89.507) than *T. crenulata* (6/ha, 6.369). However, only *T. paniculata* was recorded from the study sites of Mankulam Division and Thekkady Wildlife Division with density 20.09, 92.78 and IVI of 51.738, 93.344.

The result revealed that *T. paniculata* was dominant among the *Terminalia* species in Munnar and Kothamangalam Divisions. The sparse distribution of *T. crenulata* was noted in Kottayam and Idukki Wildlife Divisions, but in Mankulam and Thekkady Wildlife Divisions only *T. paniculata* was found. *T. travancorensis* population was negligible in Idukki Wildlife Division. However, in Marayur Sandal Division and Eravikulam National Park *T. crenulata*, *T. paniculata* and *T. travancorensis* were not found. *X. xylocarpa* was the major associate species in Munnar and Kothamangalam Divisions; whereas, *Anogeissus latifolia* was dominant in Marayur Sandal Division, *Melicope lunu-ankenda* in Mankulam Division, *Diospyros bourdillonii* in Eravikulam National Park, *Litsea beddomei* in Thekkady Wildlife Division, *T. grandis* in Idukki Wildlife Division and *Calophyllum inophyllum* in Kottayam Division.

Table 6. Basic statistics related to tree community, with special reference to *Terminalia*s in the study sites of High Range Forest Circle

Sl. No.	Parameters		
1	Total number of plots studied		59
2	Total area (ha)		13.00
3	Total number of species		163
4	Dominant tree species		*Terminalia paniculata* *Xylia xylocarpa* *Terminalia crenulata* *Lagerstroemia microcarpa* *Aporusa lindleyana* *Pterocarpus marsupium* *Tectona grandis*
5	No. of plots where trees of *Terminalias* occur	*Terminalia crenulata*	16
		Terminalia paniculata	42
		Terminalia travancorensis	1
6	Total tree density (individuals ha^{-1})		234.13 ± 5.00
7	Contribution of *Terminalias* to tree density (% of total tree density)	*Terminalia crenulata*	3.71
		Terminalia paniculata	25.18
		Terminalia travancorensis	0.03
8	Total basal area of tree community (m^2 ha^{-1})		29.0
9	Contribution of *Terminalias* to basal area of tree community (% of total basal area of tree community)	*Terminalia crenulata*	4.08
		Terminalia paniculata	28.44
		Terminalia travancorensis	0.38
10	Contribution of *Terminalias* to IVI of tree community (% of total IVI of tree community)	*Terminalia crenulata*	3.21
		Terminalia paniculata	19.52
		Terminalia travancorensis	0.17

Southern Forest Circle: Table 7 represents basic statistics of *Terminalia* species in the study sites of Southern Circle. Occurrence of *T. paniculata* was found in 97% of the study plots; whereas *T. crenulata* occurred only in 46% of the study plots. Contribution of *T. paniculata* to the total tree density, basal area and dominance was very high when compared to the other species. This indicated that *T. paniculata* was highly dominant in Southern Circle than *T. crenulata*. However, *T. travancorensis* was not found in the study sites. *P. marsupium* was the major

associate species. Structural status of tree species in the study sites is given in Appendix 6. Richness (11.99) and diversity (2.96) indices showed that species richness and diversity were lower than other Forest Circles.

In Konni Division of Southern Circle, *T. paniculata* was recorded with higher density and IVI (70.48/ha, 78.629) than that of *T. crenulata* (16.19/ha, 18.110). Density and IVI of *T. paniculata* (152.50/ha, 82.137) were higher than *T. crenulata* (18.33/ha, 13.463) in the study sites of Ranni Division. Similarly, in Achankovil Division also tree density and IVI of *T. paniculata* (75.71/ha, 74.161) were higher than *T. crenulata* (10.48/ha, 10.758). In Punalur Division *T. paniculata* was found with higher density and IVI (143/ha, 67.112) than *T. crenulata* (19/ha, 25.103). Observation from Thenmala Division showed only *T. paniculata* with a density of 208 and IVI 110.119. Tree density and IVI of *T. paniculata* (104.49/ha, 81.222) were very much higher than that of *T. crenulata* (4.90/ha, 7.892) in the study sites of Trivandrum Division. Similarly, in Trivandrum Wildlife Division, *T. paniculata* was found with a higher density and IVI (97.14/ha, 83.499) than *T. crenulata* (5.45/ha, 10.367).

Study sites in Forest Divisions of Konni, Ranni, Achankovil, Punalur, Trivandrum and Trivandrum Wildlife Division were dominated by *T. paniculata*. However, *T. crenulata* was not found in the study sites of Thenmala Division. *T. travancorensis* was not found in any of the study sites in Southern Forest Circle. *X. xylocarpa* was major associate species in the study sites of Ranni and Punalur Divisions; *L. microcarpa* in Konni Division, *G. tiliifolia* in Achankovil Division, *C. inophyllum* in Thenmala Division and *P. marsupium* in Trivandrum Territorial and Trivandrum Wildlife Divisions.

In general, overall density and dominance of *T. paniculata* were comparatively higher than that of *T. crenulata* in the study sites of Kerala. *T. travancorensis* was comparaitively minimal in distribution (Fig. 2). However, between the Forest Circles, density and dominance of *T. crenulata* were higher than that of *T. paniculata* in the Northern Circle; in other Circles *T. paniculata* was dominant. It also showed more or less an increasing trend in the occurrence of *T. paniculata* from Northern to Southern Forest Circles, whereas *T. crenulata* showed a

decreasing trend (Figs. 3, 4). Figure 5 depicts the status of distribution of *T. travancorensis* among the Forest Circles. Tree density in each Forest Circle was significantly different for *T. paniculata* (*P=0.01*) and *T. crenulata* (*P=0.05*). The study indicated that presently *T. paniculata* is more or less stable compared to *T. crenulata*. A negative correlation between *Terminalias* and *X. xylocarpa* was also noticed in the study.

Table 7. Basic statistics related to tree community, with special reference to *Terminalia*s in the study sites of Southern Forest Circle

Sl. No.	**Parameters**		
1	Total number of plots studied		35
2	Total area (ha)		9.70
3	Total number of species		98
4	Dominant tree species		*Terminalia paniculata* *Pterocarpus marsupium* *Terminalia crenulata* *Calophyllum inophyllum* *Careya arborea* *Lagerstroemia microcarpa* *Grewia tiliifolia*
5	No. of plots where trees of *Terminalias* occur	*Terminalia crenulata*	16
		Terminalia paniculata	34
		Terminalia travancorensis	0
6	Total tree density (individuals ha^{-1})		270.02 ± 10.07
7	Contribution of *Terminalias* to tree density (% of total tree density)	*Terminalia crenulata*	3.02
		Terminalia paniculata	35.81
		Terminalia travancorensis	-
8	Total basal area of tree community (m^2 ha^{-1})		38.8
9	Contribution of *Terminalias* to basal area of tree community (% of total basal area of tree community)	*Terminalia crenulata*	6.49
		Terminalia paniculata	41.04
		Terminalia travancorensis	-
10	Contribution of *Terminalias* to IVI of tree community (% of total IVI of tree community)	*Terminalia crenulata*	4.14
		Terminalia paniculata	27.54
		Terminalia travancorensis	-

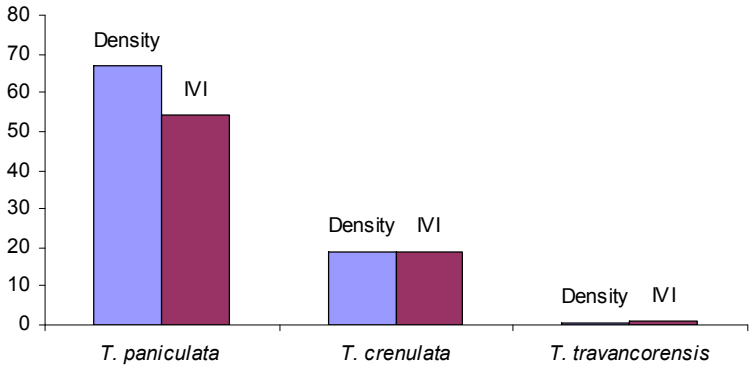

Fig. 2. Overall comparison of *Terminalia*s in the study sites of Kerala

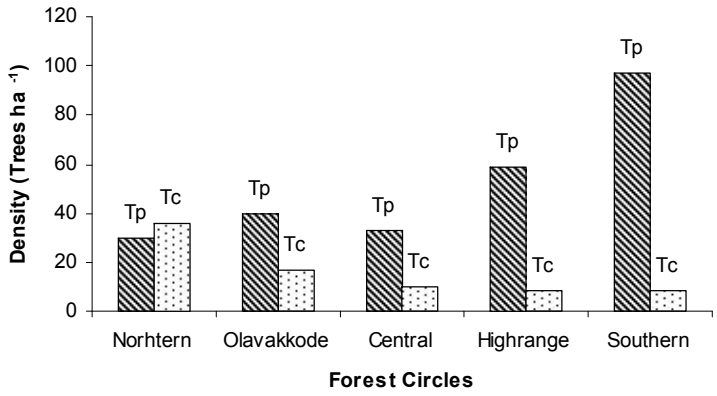

Fig. 3. Tree density of *T. paniculata* (Tp) and *T. crenulata* (Tc) in the study sites of five Forest Circles

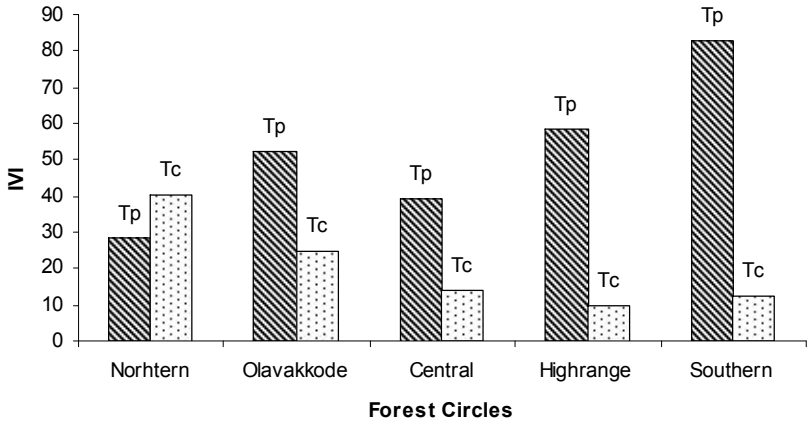

Fig. 4. IVI of *T. paniculata* (Tp) and *T. crenulata* (Tc) in the study sites of five Forest Circles

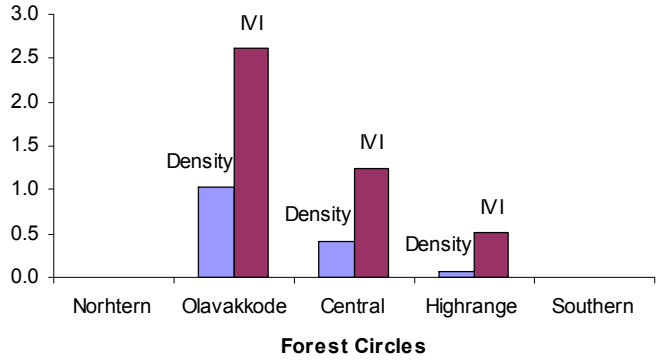

Fig. 5. Density and IVI of *T. travancorensis* in the study sites of Forest Circles

3.2. Regeneration of *Terminalias*

Regeneration status of Terminalias in the forests of Kerala

Regeneration enumeration was carried out from 218 temperory plots (51.7 ha) established in all the Divisions of Forest Circles in Kerala. Overall regeneration density of *T. paniculata*, *T. crenulata* and *T. travancorensis* and their status were estimated using the data acquired from study plots (Appendices 7, 8). Regeneration is important as it addresses mainstream biodiversity concerns and quantitative assessment of regeneration of tree species in a forest helps to predict future status of concern (Reddy and Ugle, 2008; Bhadra and Dhal, 2010). Within a primary forest, occurrence of individuals of a species in any particular spot is determined by the regeneration of that species, and it is governed by the presence of mature trees, dispersal mechanism, flowering and fruiting behaviour (Kartawinata, 1978; Menon, 2010). Nature, extent and pattern of overstorey vegetation offer distinctive resource supply regimes in forest understorey. Survival and growth of regeneration depends invariably upon efficient utilization of these resources (Singh, 2003). Following are the results of regeneration study in the forests of Kerala.

The overall regeneration of *T. paniculata*, *T. crenulata* and *T. travancorensis* from the study sites in Kerala was 73.58/ha, 18.47/ha and 0.019/ha respectively. According to Bhadra and Dhal (2010), density values of regeneration are considered as regeneration potential of the species. A good regeneration potential shows suitability of the species to the environment. Tables 8 and 9 represent

overall regeneration status of *T. paniculata* and *T. crenulata*. Forty-six per cent of *T. paniculata* were unestablished (seedlings) category (<3 cm girth class), 24% belonging to the established (saplings) category (3-9.9 cm girth class) and 30% advanced (poles) category (10-30 cm girth class). About 28% of the unestablished category were less than 50 cm height class, 51% were in 50-100 cm height class and 21% were above 100 cm height class. Fifty-six per cent of *T. crenulata* were unestablished group, 26% established and 18% advanced. About 40% of the unestablished seedlings were under less than 50 cm height class, 44% were under 50-100 cm height class and 16% were under above 100 cm height class.

Regeneration status of a species is determined based on population size of seedlings and saplings (Bhuyan *et al*., 2003). According to Khumbongmayum *et al*. (2006), regeneration is said to be good if the proportion is seedlings > saplings > adults, regeneration is fair if seedlings > or ≤ saplings > adults and regeneration is poor if the species survives only in sapling stage (saplings may be <, > or = adults). They stated that the future community structure and regeneration status of a species could be predicted from the relative proportion of seedlings and saplings in the total populations of various species in the forest. Pokhriyal *et al*. (2010) also stated that regeneration of a particular species is poor if seedlings and saplings are less than the mature trees.

The study indicated that overall regeneration of *T. paniculata* in Kerala was more as compared to *T. crenulata* and *T. travancorensis*. However, proportion of seedlings, saplings and poles of *T. paniculata* was not satisfactory (seedlings > saplings < poles). Whereas, proportion of seedlings, saplings and poles of *T. crenulata* was very good. The overall population structure of *T. crenulata* showed that contribution of seedlings to the total regeneration was higher followed by saplings and poles. It showed that regeneration of *T. crenulata* was good and the future communities may be sustained.

Regeneration of *T. travancorensis* was negligible in the study sites. Kunhikannan *et al*. (2003) stated that absence of seedlings and saplings indicate a projected local extinction of the species. According to Khumbongmayum *et al*. (2006), presence of species that represented only by adults without any seedlings and

saplings may be due to poor seed set, germination and poor establishment of seedlings in the forest. Reddy and Ugle (2008) mentioned that reduced regeneration may be a threat to the species and the population structure will be unstable and regeneration potential will be negligible if the species is represented only by adults in any forest.

Table 8. Overall regeneration status of *T. paniculata* in the study sites of Kerala (Values (individual ha^{-1}) are mean ± SE)

Regeneration categories		Density	
Seedlings (<3cm collar girth)	< 50 cm height	9.59 ± 3.13	34.04 ± 14.62
	50-100 cm height	17.37 ± 6.43	
	>100 cm height	7.08 ± 3.22	
Saplings (3.0 -9.9 cm Gbh)			17.78 ± 7.23
Poles (10.0-30.0 cm Gbh)			21.76 ± 9.67

Table 9. Overall regeneration status of *T. crenulata* in the study sites of Kerala (Values (individual ha^{-1}) are mean ± SE)

Regeneration categories		Density	
Seedlings (<3cm collar girth)	< 50 cm height	4.12 ± 1.35	10.35 ± 3.42
	50-100 cm height	4.53 ± 1.56	
	>100 cm height	1.70 ± 0.77	
Saplings (3.0 -9.9 cm Gbh)			4.78 ± 1.89
Poles (10.0-30.0 cm Gbh)			3.35 ± 1.46

Regeneration data acquired for each Forest Circle were analysed separately. The details are presented below (Tables 10, 11 and Appendices 7, 8).

Norhtern Forest Circle: Overall result from Northern Circle revealed that regeneration density of *T. paniculata* (27.80/ha) was higher than that of *T. crenulata* (11.63/ha). Of the regeneration of *T. paniculata*, seedling category was 71%, for saplings 12% and for poles 17%. Forty per cent of seedlings were < 50 cm height class, 45% were in 50-100 cm height class and 15% were >100 cm. Of the total regeneration of *T. crenulata*, 94% were seedlings, 4% belonging to saplings and 2% poles. About 30% of the seedlings were <50 cm height class, 58% were in 50-100 cm height class and 12% were >100 cm height class.

Regeneration density of *T. paniculata* (58.46/ha) in the study plots of Kannur Division of Northern Circle was higher than that for *T. crenulata* (18.08/ha). Seventy-eight per cent of the total regeneration of *T. paniculata* were under seedling group, 13% saplings and 9% poles. Forty-six per cent of the seedlings were under <50 cm height class, 47% under 50-100 cm hight class and 7% were above 100 cm hight class. All the regeneration of *T. crenulata* recorded from study sites were under seedling group, 43% of this were <50 cm height class, 47% in 50-100 cm height class and 10% in >100 cm height class. No regeneration of *Terminalia* species was noticed in Aralam Wildlife Division. Regeneration enumeration of Kozhikkod Division showed that density of *T. paniculata* (34.40/ha) was very much higher than *T. crenulata* (1.60/ha). Of the total regeneration of *T. paniculata*, 47% were seedlings, 9% belonging to saplings and 44% poles. Five per cent of the seedlings were <50 cm height class, 35% were in 50-100 cm class and 60% were >100 cm height class. Only two individuals of *T. crenulata* were found from the area, one was sapling and the other was pole. Only a single pole of *T. paniculata* found from Wayanad North Division. However, in South Division, only *T. crenulata* was found with density 30.77/ha. Among them, 95% were seedlings and 5% saplings. Ninety-five per cent of the seedlings were under 50-100 cm height class and 5% under >100 cm. In Wayanad Wildlife Division, regeneration was found only for *T. crenulata* with density 8.13/ha. Eighty-four per cent of the regeneration were seedlings, saplings and poles were 8% each. About 27% of the seedlings were in <50 cm height class, 46% were in 50-100 cm class and 27% were >100 cm.

Table 10. Regeneration status of *T. paniculata* in study sites of different Forest Circles in Kerala (Values (individual ha^{-1}) are mean ± SE)

Forest Circles	Regeneration categories					
	Seedlings (<3cm collar girth)			Total (< 3 cm collar girth)	Saplings (3.0 -9.9 cm Gbh)	Poles (10-3) cm Gbh)
	< 50 cm height	50-100 cm height	>100 cm height			
Northern	7.94 ± 3.58	8.94 ± 3.63	2.84 ± 0.87	19.72 ± 8.52	3.26 ± 1.01	4.82 ± 1.97
Olavakkode	11.39 ± 4.91	16.73 ± 7.46	5.26 ± 1.95	33.39 ± 10.32	17.21 ± 8.28	8.61 ± 2.36
Central	8.83 ± 3.95	12.34 ± 5.78	2.66 ± 0.61	23.83 ± 9.94	34.15 ± 11.14	42.45 ± 15.60
High Range	3.46 ± 1.57	14.38 ± 7.66	8.23 ± 3.74	26.08 ± 11.29	13.00 ± 4.85	21.46 ± 7.84
Southern	17.42 ± 7.10	33.20 ± 11.36	15.26 ± 3.65	65.88 ± 19.09	19.59 ± 6.70	31.44 ± 10.41

Table 11. Regeneration status of *T. crenulata* in study sites of different Forest Circles in Kerala (Values (individual ha^{-1}) are mean ± SE)

Forest Circles	Regeneration categories					
	Seedlings (<3cm collar girth)			Total (< 3 cm collar girth)	Saplings (3.0 -9.9 cm Gbh)	Poles (10-30 cm Gbh)
	< 50 cm height	50-100 cm height	>100 cm height			
Northern	3.26 ± 0.68	6.38 ± 2.87	1.28 ± 0.58	10.92 ± 5.16	0.43 ± 0.18	0.28 ± 0.09
Olavakkode	9.32 ± 3.27	4.70 ± 1.43	0.96 ± 0.21	14.98 ± 6.83	1.67 ± 0.53	1.20 ± 0.50
Central	4.57 ± 1.75	6.17 ± 2.63	1.17 ± 0.41	11.91 ± 4.37	19.79 ± 7.89	11.28 ± 5.88
High Range	1.77 ± 0.49	2.69 ± 0.88	2.31 ± 0.86	6.77 ± 2.75	2.00 ± 0.55	2.31 ± 0.41
Southern	0.72 ± 0.17	3.81 ± 1.23	2.68 ± 0.98	7.22 ± 2.18	1.13 ± 0.77	2.06 ± 0.54

Division-wise analysis revealed that regeneration density of *T. paniculata* in Kannur and Kozhikkod Divisions was more than that of *T. crenulata*. As per the criteria suggested by Khumbongmayum *et al*. (2006), regeneration status of *T. paniculata* in the study sites of Kannur Division was good, whereas in Kozhikkod Division it was poor. All the regeneration of *T. crenulata* in Kannur Division was under seedling category. However, in Kozhikkod Division regeneration for *T. crenulata* was minimal. Regeneration in Wayanad South and Wayanad Wildlife Division was found only for *T. crenulata*. Their status was very poor (seedlings > saplings) and the seedling category noticed only for less than 50 cm height class, and above 100 cm height class in Wayanad South Division. Whereas in Wayanad Wildlife Division regeneration status was poor (seedlings > saplings < poles) when compared to Wayanad South Division. However, in Wayanad North Division regeneration was negligible for *T. paniculata* and absent for *T. crenulata*. No regeneration of *Terminalia* species was found from the study sites of Aralam Wildlife Division.

Olavakkode Forest Circle: Overall result of the study from Olavakkode Circle showed that regeneration density of *T. paniculata* (59.20/ha) was higher than that of *T. crenulata* (17.78/ha). However, only a single pole of *T. travancorensis* was found from the study sites with density 0.079/ha. Fifty-six per cent of *T. paniculata* were seedlings, 29% saplings and 15% poles. Thirty-four per cent of the seedlings were under <50 cm height class, 50% under 50-100 cm class and

16% under >100 cm. Eighty-four per cent of the *T. crenulata* were seedlings, 9% saplings and 7% poles. Sixty-two per cent of the seedlings were <50 cm height class, 31% were in 50-100 cm class and 6% were >100 cm height class.

Regeneration of *T. paniculata* (94.71/ha) was more in Nilambur North Division of Olavakkode Circle than that of *T. crenulata* (52.94/ha). Seventy-one per cent of *T. paniculata* regeneration was under seedling group, 22% saplings and 7% poles. Thirty-five per cent of the seedlings were in <50 cm height class, 46% were in 50-100 cm class and 19% were >100 cm. Ninety-two per cent of *T. crenulata* regeneration were under seedling category, 6% saplings and 2% poles. About 63% of the seedlings were under <50 cm height class, 30% under 50-100 cm class and 7% under >100 cm height class. In Nilambur South Division also regeneration of *T. paniculata* (73.94ha) was higher than tht of *T. crenulata* (12.73ha). Sixty-one per cent of *T. paniculata* were seedlings, 29% saplings and 10% poles. Forty-two per cent of the seedlings were in <50 cm height class, 55% were in 50-100 cm class and 3% were >100 cm. Seventy-six per cent of the *T. crenulata* were seedlings, 19% saplings and 5% poles. Fifty-six per cent of the seedings were in <50 cm height class and 44% were in 50-100 cm class. However, in Mannarghat Division, only *T. paniculata* was found with density of 7.62/ha. Sixty-three per cent of them were seedlings, 25% saplings and 12% poles. About 40% of the seedlings were <50 cm, 40% were in 50-100 cm class and 20% were >100 cm.

Regeneration of *T. paniculata* (69.84/ha) from the study sites of Palakkad Division was also higher than that of *T. crenulata* (3.93/ha). Of the total regeneration of *T. paniculata*, 37% were seedlings, 39% were saplings and 24% were poles. Twenty-three per cent of seedlings were in <50 cm height class, 58% were in 50-100 cm class and 19% were >100 cm. Twenty-five per cent of *T. crenulata* were seedlings, 42% were saplings and 33% were poles. The seedling group was equally distributed in the three height classes. Regeneration of *T. paniculata* (73/ha) in the Nenmara Division was much higher than *T. crenulata* (7/ha). Forty-four per cent of the total regeneration of *T. paniculata* were seedlings, 31% saplings and 25% poles. Thirty-eight per cent of seedlings were in <50 cm height class, 53% were in 50-100 cm class and 9% were >100 cm. Of the total regeneration of *T. crenulata*, 29% were seedlings, 14% saplings and 57%

poles. The seedlings were equally distributed under <50 cm and 50-100 cm height classes. In Parambikulam Wildlife Division, *T. paniculata* regeneration (2.56/ha) was higher than that of *T. travancorensis* (0.51/ha). Twenty-per cent of the regeneration of *T. paniculata* were seedlings (>100 cm height class) and 80% were poles. Only a single pole of *T. travancorensis* was found from the study sites. In Silent valley NP, regeneration was found only for *T. crenulata* (8.89/ha). One-third of them were seedlings and two-third were poles and all the seedlings were under <50 cm height class.

The study revealed that regeneration of *T. paniculata* in the study sites of Nilambur North, Nilambur South, Palakkad and Nenmara Divisions was higher as compared to other species. Regeneration status of *T. paniculata* in Nilambur North and South Divisions was good (seedlings > saplings > poles), whereas in Palakkad and Nenmara Divisions it was fair (seedlings < saplings > poles). However, regeneration in Parambikulam Wildlife Division was very poor with a status of seedlings (>100 cm height class) < poles. Regeneration was found only for *T. paniculata* in Mannarghat Division with a very good status (seedlings > saplings > poles). With respect to *T. crenulata* in Nilambur North & South, and Nenmara Divisions, regeneration status was very good similar to *T. paniculata*. Occurrence of *T. crenulata* regeneration was minimal in study sites of Palakkad Division. In Silent valley National Park also regeneration was minimal with a status of 1:2 *T. crenulata* seedlings and poles. However, regeneration of *T. travancorensis* was found only from Parambikulam Wildlife Division with negligible occurrence.

Cerntral Forest Circle: Overall regeneration of *T. paniculata* (100.43/ha) in the study sites of Cerntral Circle was more than that of *T. crenulata* (42.98/ha). Twenty-four per cent of *T. paniculata* were seedlings, 34% saplings and 42% poles. Thirty-seven per cent of the seedlings were under <50 cm height class, 52% were under 50-100 cm classand 11% under >100 cm. Twenty-eight per cent of *T. crenulata* were seedlings, 46% saplings and 26% poles. Thirty-eight per cent of seedlings were <50 cm height class, 52% were in 50-100 cm category and 10% were >100 cm height class.

Regeneration of *T. paniculata* (145.85/ha) in Chalakkudi Division of Central Circle was more than that of *T. crenulata* (41.46/ha). Thirty per cent of the *T. paniculata* were under seedling category, 33% under saplings and 37% under poles. Twenty-four per cent of the seedlings were <50 cm height class, 56% were in 50-100 cm class and 20% were >100 cm. In the case of *T. crenulata*, 66% were seedlings, 33% were saplings and one per cent were poles. Forty-one per cent of the seedlings were <50 cm height class, 46% were in 50-100 cm class and 13% were >100 cm. In Malayatur Division, regeneration of *T. paniculata* (77.14/ha) was higher than that of *T. crenulata* (64.49/ha). Of the total regeneration of *T. paniculata*, 11% were seedlings, 55% saplings and 34% poles. Thirty per cent of the seedlings were under <50 cm height class, 70% under 50-100 cm class. With respect to *T. crenulata*, 5% of the regeneration were seedlings, 73% saplings and 22% poles. About 75% of seedlings were under 50-100 cm height class and 25% above 100 cm. In Peechi-Vazhani Wildlife Division also the *T. paniculata* regeneration (173.33/ha) was higher than that of *T. crenulata* (63.70/ha). Of the regeneration of *T. paniculata* 27% were seedlings, 44% were saplings and 29% were poles. About 40% of the seedlings were in <50 cm height class, 55% were in 50-100 cm class and 5% were >100 cm. Forty-seven per cent of *T. crenulata* were seedlings, 38% saplings and 15% poles. Thirty-eight per cent of seedlings were under <50 cm height class, 57% under 50-100 cm category and 5% under >100 cm. Regeneration of *T. paniculata* (111/ha) in Thrissur Division was also higher than *T. crenulata* (37.50/ha). Of the *T. paniculata* regeneration, 23% were seedlings, 7% were saplings and 70% were poles. Sixty per cent of seedlings were <50 cm height class, 32% were in 50-100 cm class and 8% were >100 cm. Eleven per cent of *T. crenulata* were seedlings, 12% were saplings and 77% were poles. Sixty-three per cent of the seedlings were in <50 cm height class, 37% were in 50-100 cm class and 5% were in >100 cm height class.

Regeneration of *T. paniculata* was higher in Forest Divisions of Chalakkudi, Malayatur, Thrissur and Peechi-Vazhani Wildlife Division of the Cerntral Circle. However, their regeneration status was poor in Chalakkudi (seedlings < saplings < poles), Malayatur (seedlings < saplings > poles) and Thrissur (seedlings > saplings < poles) Divisions. Regeneration status in Peechi-Vazhani Wildlife Division was same as that in Malayatur Division. In the case of *T. crenulata*,

regeneration status in Chalakkudi Division and Peechi-Vazhani Wildlife Division was very good (seedlings > saplings > poles). In Malayatur Division it was fair (seedlings < saplings > poles, whereas in Thrissur Division it was poor (seedlings < saplings < poles). However, no regeneration was found from the study sites of Vazhachal Division for any of the *Terminalia* species.

High Range Forest Circle: Overall regeneration of *T. paniculata* (60.54/ha) was very much higher than that of *T. crenulata* (11.08/ha) in the High Range Circle. Regeneration of *T. travancorensis* was not found from any of the study sites. Forty-three per cent of the *T. paniculata* were under seedling group, 22% were saplings and 35% were poles. Thirteen per cent of seedlings were under <50 cm height class, 55% under 50-100 cm class and 32% under >100 cm height class. Sixty-one per cent of *T. crenulata* were seedlings, 18% were saplings and 21% were poles. Twenty-six per cent of seedlings were under <50 cm height class, 40% were under 50-100 cm class and 34% were under >100 cm height class.

Regeneration of *T. paniculata* (50.98/ha) was higher Munnar Division in High Range Circle than the *T. crenulata* (21.96/ha). Thirty-two per cent of *T. paniculata* were under seedling category, 35% saplings and 33% poles. Twelve per cent of the seedlings were in <50 cm height class, 61% were in 50-100 cm class and 27% were >100 cm height class. Forty-six per cent of *T. crenulata* were seedlings, 32% saplings and 21% poles. Thirty-five per cent of the seedlings were in <50 cm height class, 42% were in 50-100 cm class and 23% were >100 cm. Regeneration of *T. paniculata* (52.20/ha) was very much higher in the Idukki Wildlife Division than *T. crenulata* (1.46/ha). Thirty-three per cent of *T. paniculata* were under seedling group, 32% saplings and 35% poles. About 6% of the seedlings were under <50 cm height class, 60% under 50-100 cm height class and 34% under >100 cm. In Kothamangalam Division, regeneration of *T. paniculata* (109.68/ha) was higher than *T. crenulata* (26.13/ha). Fifty per cent of *T. paniculata* were seedlings, 17% saplings and 33% poles. Twelve per cent of the seedlings were <50 cm height class, 52% were in 50-100 cm class and 36% were >100 cm height class. Sixty-nine per cent of *T. crenulata* were seedlings, 10% saplings and 21% poles. Twenty per cent of the seedlings were under <50 cm height class, 37% under 50-100 cm class and 43% under >100 cm. Regeneration

of *T. paniculata* (100.67/ha) was higher than *T. crenulata* (2.67/ha) in Kottayam Division. Fifty per cent of *T. paniculata* were seedlings, 12% saplings and 38% poles. Twenty per cent of the seedlings were <50 cm height class, 58% were in 50-100 cm class and 22% were >100 cm height class. However, in the Thekkadi Wildlife Division, only *T. paniculata* regeneration was found with density 17.14/ha. Twenty-three per cent of them were seedlings, 15% saplings and 62% poles. Of the seedlings, 22% were under <50 cm height class, 67% under 50-100 cm class and 11% under >100 cm height class. Similarly, in Mankulam Division also only *T. paniculata* was found from the study sites with density 25/ha. Fifty per cent of them were seedlings, 30% saplings and 20% poles. Ten per cent of the seedlings were in <50 cm height class, 40% were in 50-100 cm class and 50% were >100 cm.

Regeneration of *T. paniculata* in the study sites of the Forest Divisions of Munnar, Kothamangalam, Kottayam and Wildlife Divisions of Thekkadi and Idukki of High Range Circle was higher than that of *T. crenulata*. Regeneration status of *T. paniculata* in the study area of Munnar Division was fair (seedlings < saplings > poles). However, in Kothamangalam and Kottayam Forest Divisions, Thekkadi and Idukki Wildlife Divisions it was poor (seedlings > saplings < poles). In the case of *T. crenulata*, regeneration status in the study sites of Kothamangalam Division was poor (seedlings > saplings < poles). In Kottayam Division and Idukki Wildlife Division, regeneration of *T. crenulata* was minimal, whereas it was not found from Thekkadi Wildlife Division. However, Marayur Sandal Division and Eravikulam National Park were devoid of the regeneration of *Terminalia* species.

Southern Forest Circle: Generally, regeneration of *T. paniculata* (116.91/ha) was very much higher in the study sites of Southern Forest Circle than that of *T. crenulata* (10.41/ha). Fifty-six per cent of the *T. paniculata* were under seedling category, 17% saplings and 27% poles. Twenty-seven per cent of the seedlings were in <50 cm height class, 50% were in 50-100 cm clss and 23% were >100 cm. Sixty-nine per cent of *T. crenulata* were in seedling group, 11% were saplings and 20% were poles. Ten per cent of the seedlings were under <50 cm height class, 53% under 50-100 cm category and 37% under >100 cm height class.

Regeneration of *T. paniculata* (94.38/ha) in Ranni Division of Southern Circle was also very much higher than that of *T. crenulata* (11.25/ha). Sixty-nine per cent of *T. paniculata* were under seedling category, 5% saplings and 26% poles. Twenty-one per cent of the seedlings were in <50 cm height class, 48% were in 50-100 cm class and 31% were in >100 cm height class. Eighty-three per cent of *T. crenulata* were seedlings and 17% were poles. Forty-seven per cent of the seedlings were in 50-100 cm height class and 53% were in >100 cm height class. In Konni Division, regeneration of *T. paniculata* (63.81/ha) was higher than that of *T. crenulata* (25.71/ha). Eighty-one per cent of the *T. paniculata* were seedlings, 6% saplings and 13% poles. Twenty-eight per cent of the seedlings were under <50 cm height class, 46% under 50-100 cm class and 26% under >100 cm. All the *T. crenulata* regeneration were under seedling group (15% <50 cm, 52% 50-100 cm and 33% >100 cm).

Regeneration of *T. paniculata* (95.76/ha) in Achancovil Division was very much higher than that of *T. crenulata* (4.24/ha). Forty-eight per cent of *T. paniculata* were seedlings, 24% were saplings and 28% were poles. Twenty-six per cent of seedlings were under <50 cm height class, 53% under 50-100 cm class and 21% under >100 cm. Fourteen per cent of *T. crenulata* were seedlings, 29% were saplings and 57% were poles. In Punalur Division also regeneration of *T. paniculata* (170/ha) was very much higher than that of *T. crenulata* (14/ha). Fifty-six per cent of *T. paniculata* were under seedling group, 16% saplings and 28% poles. Twenty five per cent of the seedlings were in <50 cm height class, 55% were in 50-100 cm category and 20% were >100 cm height class. In the case of *T. crenulata*, 86% were seedlings and 14% were poles. Regeneration in the Thenmala Division was found only for *T. paniculata*. Sixty-five per cent of these were in seedling category, 16% saplings and 19% poles. Thirty per cent of the seedlings were in <50 cm height class, 55% were in 50-100 cm class and 15% were >100 cm height class.

Regeneration of *T. paniculata* (113.33/ha) in the study area of Trivandrum Division was also very much higher than that of *T. crenulata* (4.17/ha). Forty-six per cent of *T. paniculata* were seedlings, 16% saplings and 38% poles. Sixteen per cent of the seedlings were in <50 cm height class, 57% were in 50-100 cm

category and 27% were >100 cm. Twenty per cent of *T. crenulata* were under seedling group (50-100 cm height class) and 80% were poles. In Trivandrum Wildlife Division also regeneration of *T. paniculata* (143.18/ha) was higher than that of *T. crenulata* (13.64/ha). Fifty per cent of *T. paniculata* regeneration were under seedling group, 22% under saplings and 28% under poles. About 32% of the seedlings were in <50 cm height class, 44% were in 50-100 cm height class and 23% were >100 cm height class. Forty-seven per cent of the regeneration of *T. crenulata* were seedlings, 30% saplings and 23% poles. Seven per cent of the seedlings were under <50 cm height class, 36% were in 50-100 cm height class and 57% were in >100 cm height class.

Regeneration of *T. paniculata* in the study sites of Forest Divisions of Ranni, Konni, Punalur, Trivandrum, and Trivandrum Wildlife Division was higher than that of *T. crenulata*. Regeneration status of *T. paniculata* in the study sites of Konni and Achancovil Divisions was very good (seedlings > saplings > poles), whereas it was poor (seedlings > saplings < poles) in the Forest Divisions of Ranni, Punalur, Trivandrum and Trivandrum Wildlife Division. However, in Thenmala Division, regeneration was found only for *T. paniculata* with a poor status. With respect to *T. crenulata*, regeneration status in Trivandrum Wildlife Division was very good (seedlings > saplings > poles) whereas in Achancovil Division, it was very poor (seedlings < saplings < poles). Regeneration status was seedlings > poles in Ranni Division and seedlings < poles in Punalur Division. Regeneration status in Trivandrum Division was seedlings < poles and all the regeneration in the study sites of Konni Division were under seedling category.

Comparison between Forest Circles revealed that overall regeneration status of *T. paniculata* in Olavakkode Forest Circle was very good (seedlings > saplings > poles). However, it was poor (seedlings > saplings < poles) in Northern, Cerntral, High Range and Southern Circles. Seedling (unestablished group) status in all the Circles was more or less fair. The regeneration status of *T. crenulata* in Northern and Olavakkode Circle was very good (seedlings > saplings > poles) with a fair and good seedling status respectively, whereas in Cerntral Circle it was fair (seedlings < saplings > poles) with a poor seedling status. However, in High Range and Southern Circles it was poor (seedlings > saplings < poles). A

significant difference (*P=0.01*) in regeneration density of *T. paniculata* and *T. crenulata* was found between Forest Circles. Sharma and Raghubanshi (2006) stated that difference in relative proportion of the three categories of regeneration may be due to interactive influence of an array of biotic and abiotic factors.

Variations in the population structure of regeneration may be attributed to differences in their habitat and prevailing microenvironmental factors. Good and Good (1972) have considered three major components which cause successful regeneration of tree species such as ability to initiate new seedlings, ability of seedlings and saplings to survive and ability of seedlings and saplings to grow. Other authors reported that open canopy may favour germination and seedling establishment by increased incidence of solar radiation on the forest floor and consequent increase in surface temperature, and reduced competition from the canopy layer (Khan *et al*., 1987; Srinivas, 1992). Light penetration to the ground is a major factor for seed germination and establishment of regeneration (Ashton, 1988; Manokaran and LaFrankie, 1990). Tripathi and Khan (1990) stated that microsite characteristics of forest floor and microenvironmental conditions under the forest canopy influence the regeneration. Sharma and Raghubanshi (2006) reported that regeneration of tree species is poor at *Lantana camara* invaded site due to increased allelopathic suppression of tree seedlings. According to Adam and El Tayeb (2008), lack of natural regeneration ultimately affects the regular distribution of diameter classes, and consequently the performance of the tree in its ecological and production functions.

The study showed that regeneration of the species is favoured only under <40% canopy cover. Observation in the study also revealed that regeneration of *X. xylocarpa* had a negative influence on the establishment of the regeneration of *Terminalia* species upto a certain limit. Reduced amount of light that reaches the forest floor is responsible for the decline of tree seedlings (Sharma and Raghubanshi, 2006). Sapkota and Oden (2009) reported that relative seedling density of *Terminalia alata* increases with increase in gap areas. Since *T. travancorensis* is an evergreen species, negligible occurrence of its regeneration might be due to thick litter accumulation and closed canopy, which reduce seed germination (Pokhrial *et al*., 2010).

In general, regeneration of a species is affected by anthropogenic factors and natural phenomena like fire, grazing, litter production, drought, heavy rain, canopy structure of overstorey, etc. (Narayanan and Swarupanandan, 1996; Khumbongmayum *et al*., 2006; Reddy and Ugle, 2008; Menon, 2010). The study also revealed that about 90% of the regeneration of *T. paniculata* and *T. crenulata* was root suckers or resprouts. Over time, the species may become dominated by clonal root-sprouters (Saha and Howe, 2003). According to Ganesan and Setty (2004), larger proportion of the population of seedlings and saplings than poles may constitute a future population bottleneck. However, regeneration of *Terminalia* species in the present study was not in par with their mature trees.

3.3. Regeneration dynamics of *T. paniculata* and *T. crenulata*

In view of the assessment of regeneration dynamics, observation on growth pattern of different categories of regeneration was carried out in the permanent plots. Regeneration of *T. paniculata* was found with a density of 31.2 at the time of initial observation (March 2006) from the 1.25 ha permanent plot at Nilambur. Of this, 43.6% were under seedling group, 46.2% saplings and 10.2% poles. After six months (September 2006) duration the regeneration increased to 38.4/ha with a seedling population 27.1% of the total regeneration, sapling population 54.2% and poles 18.7%. However, the regeneration suffered a heavy mortality upto September 2007. There after a prominent increase in regeneration (116/ha) was noticed at the 24^{th} month of observation (March 2008) with a seedling population 8.3%, sapling population 34.5% and poles 57.2%. However, regeneration of *T. crenulata* was only 1.6 per hectare at 6^{th} month and 2.4 per hectare at 24^{th} month. Figures 6 and 7 depict regeneration dynamics of *T. paniculata*. During the study period new recruitment of *T. paniculata* was noticed at a rate of 20 per hectare and for *T. crenulata* at the rate of 7.2 per hectare.

Initially, regeneration status of *T. paniculata* in the study sites of permanent plot was only fair (seedling < sapling > pole). Though the regeneration of *T. paniculata* increased to about 21% after six months, its status remained same as initial stage. Poor regeneration for the next one year might be due to low seeding and poor seed germination. Increase in regeneration reported during 24^{th} month of observation might be due to the effect of favourable climatic condition. Poor

status in regeneration (seedling < sapling < pole) might be due to regeneration dynamics, i.e., changing of seedlings to saplings then to poles during the course of growth. The low sapling population may be attributed to the adverse impact of environmental factors prevalent during the sapling growth, whereas greater proportion of saplings than seedlings may be due to poor seed set and seed germination (Khumbongmayum *et al*., 2006). Regeneration of *T. crenulata* in the study sites was only minimal. New recruitment of *T. paniculata* was also higher than that of *T. crenulata*. Khumbongmayum *et al*. (2006) observed that greater proportion of seedlings followed by saplings and adults varies seasonally and absence of seedlings and saplings may be due to poor seed germination and establishment of seedlings in the forest.

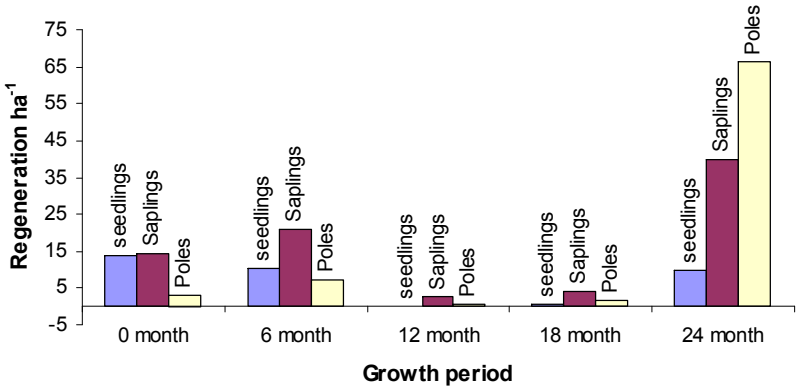

Fig. 6. Overall regeneration dynamics of the study site

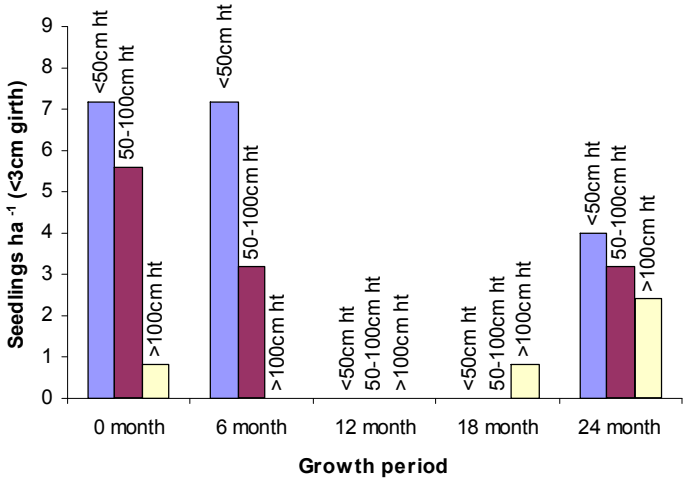

Fig. 7. Seedling (<3 cm collar girth) dynamics of the study site

3.4. Phenology

Phenological study - timing of recurring biological events, among phases of the plant species, which provide a background for collecting and synthesizing detailed quantitative information on rhythms of plant communities, helps to understand regeneration process of the species. Study of phenological events is useful in evolving proper management strategy as well as better understanding of natural regeneration potential. Climatic factors are mainly responsible for vegetative and reproductive phenology. But phenology of the *Terminalias* is not well understood except few events reported by FRI (1984).

Leaf shedding of *Terminalia* species commenced in January and continued up to April. However, trees of *T. travancorensis* were leafless during January, where as *T. crenulata* and *T. paniculata* trees were leafless during February and March. Similar event was reported in Troup's Silviculture of Indian Trees (FRI, 1984). Trees of *T. travancorensis* were in flush (young leaves) during February and March. Flushing of *T. crenulata* and *T. paniculata* was between the month of October and March. Flowering of *T. crenulata* and *T. paniculata* commenced from April and continued upto July. Flowering in *T. travancorensis* commenced from May and continued upto January. Fruits of *T. crenulata* and *T. paniculata* matured from December to February and for *T. travancorensis*, from September to June. The various phenological events are triggered by rainfall, water availability, temperature, photoperiods, duration of dry spell and change in daylength.

3.5 Seed characteristics

The best time for *T. crenulata* seed collection is just after leaf shedding and when the wings turn into black (Chacko *et al*., 2002). *T. crenulata* fruit is a drupe with a size of 3-4 x 3.5 cm having 4-5 coreacious wings and is brown when ripe. Fruit contains pale yellow coloured single seed. Mean fruit weight is 750 numbers per kilogram. Storage physiology of *T. crenulata* seed is Intermediate (can be dried to a moisture content as that of Orthodox seeds - 4-8% moisture content, but sensitive to low temperature) (CABI, 1998) with 80% viable seeds. Viability of seeds can be retained for one year in sealed tin/gunny bags (Chacko *et al*., 2002). Best pre-sowing treatment is de-winging and water soaking for 24 hours.

T. paniculata fruit is a drupe similar to *T. crenulata* with a size of 1.5 x 0.8 cm having 3 unequal wings with a single seed and is brick red when ripe. The size of fruits varies considerably and average fruit weight is 46100 numbers per kilogram. The storage physiology of the seeds of *T. paniculata* is probably Orthodox (Chacko *et al*., 2002). Seed emptiness is very high, i.e., only upto four per cent seeds are viable. The high infertility of *T. paniculata* seeds has been ascribed partially if not wholly, to weevil like, *Nanophyes terminaliae*, *Carella rotundipennis* that feed on the flowers and developing fruits (FRI, 1984). It was reported that the infertility may be also due to fungi like, *Drechslera australensis*, *Myrothecium* sp., *Graphium* sp., *Ascochyta* sp., *Phomopsis* sp., etc. (Chacko *et al*., 2002). Viability of seeds can be retained for five months by storing in sealed tin/gunny bags. Pre-sowing treatment is not necessary for enhancing seed germination; however, water soaking for 24 hours gives a better result. *T. travancorensis* fruit also is a drupe, obovoid and looks like that of *T. chebula*. However *T. travancorensis* fruits are covered with prominent lenticels, a character which serves to distinguish it from other *Terminalia* species with a size of 2.5-4.6 x 1.6-2.0 cm contains single seed. Average fruit weight is 400 numbers per kilogram. The seed is Orthodox and 85% seeds are viable. Viability of seeds can be retained for one year in sealed tin/gunny bags. The best pre-sowing treatment is weathering (wetting and drying for seven days) to enhance germination.

3.6. Seed germination

T. paniculata gave only 0.75% germination, whereas *T. crenulata* had 40% germination. Only four per cent viable seeds were noticed in *T. paniculata*; however, it was 75% in *T. crenulata* seeds. In the case of *T. travancorensis* pre-treatments enhanced seed germination and maximum (35%) germination was obtained when the seeds were subjected to weathering treatment (wetting and drying for seven days - T_1); very low germination (3%) was found in the split treatment (T_3) (Table 12 & Fig. 8). ANOVA also revealed significant ($P = 0.01$) treatment effect on germination.

The study revealed that germination of *T. paniculata* was negligible due to the infertility and heavy pest infestation. Insects like *Nanophyes terminaliae* and *Garella rotundipennis* attack both flowers and young fruits, which causes heavy

damage of mature fruits (FRI, 1984). However, in the case of *T. crenulata* germinability of seeds was more or less fair. With respect to *T. travancorensis*, weathering treatment of seeds was needed to get a better germination. Seeds without pre-treatment (T_0) showed little change in the germination percentage after 68 days of sowing. However, seeds subjected to weathering treatment (T_1) continued to germinate even upto 101 days after sowing (Fig. 8). In a 45 days observation, Omalsree *et al*. (2010) reported that germination of teak seeds can be increased by weathering treatment (alternate wetting and drying for 7 days).

Table 12. Mean germination of different treatments in *T. travancorensis*

Sl. No	Treatment code	Treatment	Germination %
1	T_0	Control	25.75 ± 4.50
2	T_1	Weathering	34.50 ± 7.05
3	T_2	De-pulped & weathering	12.50 ± 3.32
4	T_3	De-pulped & Split	2.67 ± 1.31

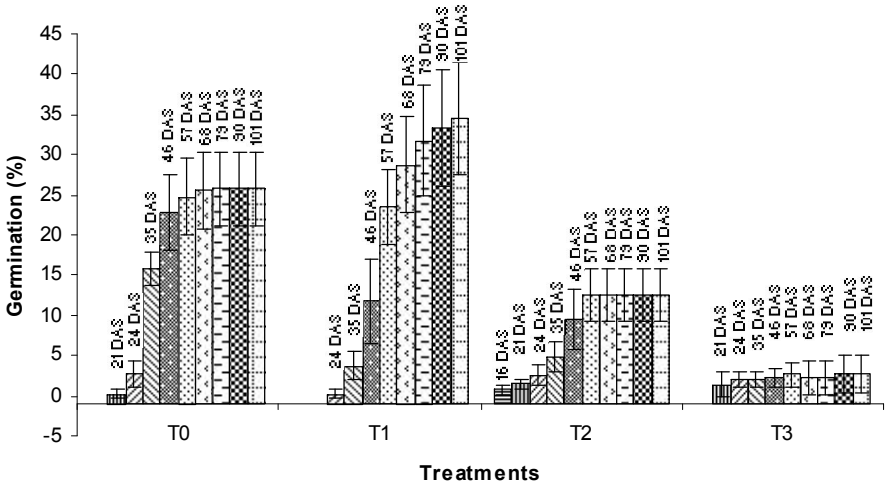

Fig. 8. Germination pattern of *T. travancorensis* with respect to treatments (T0 – control; T1 – weathering; T2 – de-pulped & weathering; T3 - de-pulped & split)

3.7. Vegetative propagation

Juvenile shoots from the branches of mature trees of *T. crenulata*, *T. paniculata* and *T. travancorensis* showed negative respose to the rooting hormones. Shoots from the established seedlings of *T. travancorensis* responded to rooting

hormones. The response of rooting to different hormone concentrations is given in Table 13. Maximum rooting was found in the auxin combination IBA+Kinetin 6000 ppm. Lowest rooting was observed in control indicating the need for hormonal treatment for enhanced rooting. Similarly, maximum root length was also in IBA+Kinetin 6000 ppm followed by IBA+Kinetin 8000 ppm and IBA+Kinetin 7000 ppm. The result was statistically analyzed using ANOVA, which showed significant difference ($P = 0.05$) between treatments.

Juvenile shoots from the branches of mature trees of *T. crenulata*, *T. paniculata* and *T. travancorensis* were not resposive to the rooting hormones. However, juvenile shoots from established seedlings of *T. travancorensis* showed a positive response to rooting hormones. The study revealed that natural regeneration of the species in the original habitat is very meager probably due to the impact of microclimate without much canopy gap. For conserving such important species, artificial regeneration is one of the effecticve tools to sustain the population. Plantable seedlings also can be produced from seeds by subjecting them to suitable pre-treatments (Pillai and Subin, 2010).

Table 13. Rooting response of single nodded cuttings of *T. travancorensis*

Treatment code	Treatment	Rooting %	No. of roots	Max. root length (cm)	Min. root length (cm)
T_0	Control	37.50	1.6 ± 0.7	3.0 ± 1.8	1.1 ± 0.7
T_1	IBA+Kinetin 5000 ppm	64.75	4.1 ± 1.2	3.6 ± 1.6	1.9 ± 0.9
T_2	IBA+Kinetin 6000 ppm	70.83	10.8 ± 3.8	5.0 ± 1.8	1.5 ± 0.6
T_3	IBA+Kinetin 7000 ppm	53.85	7.9 ± 3.6	2.4 ± 0.8	1.0 ± 0.6
T_4	IBA+Kinetin 8000 ppm	62.48	10.2 ± 4.8	3.0 ± 1.1	1.4 ± 0.9

3.8. Package of nursery practices

Ripened fruits of *T. crenulata* should be collected from the clean ground or trees during the month of March and April. Ground-cleaning ensures that none of the early fallen seeds are collected. The fruits should be dried in the sun for 3-4 days

and stored in gunny bags in a dry well-ventilated shed for a month. Pre-sowing treatment like de-winging and 24 hours water soaking helps to enhance seed germination. The wings are removed either by using scissors or crushing the fruits to break the wings. The pre-treated seeds are dibbled 7.5 x 7.5 cm apart in shaded raised beds (FRI, 1984). In a standard bed (12 x 1.2 m) about 4-5 kg *T. crenulata* seeds can be sown to prduce 840-1050 qualty plantable seedlings. Quality seeds will give 40% germination with a plant percentage of 70. It should be dibbled with the fruit stalk end downwards at a depth equal to its diameter. The nursery bed should be moistened by regular watering, atleast once in a day (preferably between 3 to 4 pm). Germination will commence within ten days and continue upto 35 days. Seedlings at 3 or 4 leaf stage are polypotted in bags of 22.5 x 17.5 cm size filled with potting mixture of soil, sand and cow-dung (3:2:1).

Mature fruits of *T. paniculata* should be collected from trees by lopping off the branches during March and April when they attain brick red colour. The fruits should be dried in the sun for one or two days and stored in gunny bags in a dry well ventilated shed for a month. Treatment of seeds before sowing is not necessary. Since the seed germination is very poor (<1%), large quantity of seeds are heaped together and watered daily; when the seeds begin to sprout, they are removed and polypotted in bags of 22.5 x 17.5 cm size filled with potting mixture of soil, sand and cow-dung (3:2:1).

Ripened fruits of *T. travancorensis* should be collected from clean ground or trees. The fruits should be dried under shade and stored in gunny bags for a month. Weathering treatment (wetting and drying for seven days) helps to enhance seed germination. The pre-treated seeds are dibbled 10 x 10 cm apart in shaded raised standard beds. About 3-4 kg *T. travancorensis* seeds can be sown to prduce 300-400 quality plantable seedlings. Quality seeds will give 35% germination with a plant percentage of 70. It should be dibbled at a depth equal to its diameter. The nursery bed should be moistened by regular watering. Germination will commence within 3-4 weeks and will continue upto 100 days. Seedlings at 3 or 4 leaf stage are polypotted in bags of 22.5 x 17.5 cm size filled with potting mixture of soil, sand and cow-dung (3:2:1).

4. Conclusions

The study revealed that density and abundance of the mature trees of *T. paniculata* was higher than that of *T. crenulata*. This indicated that presently the population of *T. paniculata* is more less stable compared to *T. crenulata*. However, occurrence of *T. travancorensis* was minimal and limited to a few localities. Total regeneration of *T. paniculata* was more when compared to *T. crenulata* and *T. travancorensis*. The contribution of seedling group to the total population of *T. paniculata* was higher than that of saplings and poles; whereas saplings were lower than poles. This indicated that the status of *T. paniculata* regeneration was not fair. Though regeneration of *T. crenulata* was comparatively lower than that of *T. paniculata*, the contribution of seedlings to its total population was highest followed by saplings and poles that showed a good regeneration status. However, the regeneration of *T. travancorensis* was negligible. Regeneration of *Terminalia* species was not in par with their mature trees. Germination of *T. paniculata* was negligible due to the infertility and heavy pest infestation. Seeds of *T. travancorensis* would need a pre-treatment for better germination. Juvenile shoots from the established seedlings of *Terminalia* species were found to respond to rooting hormones as an alternate means of propagation. For conserving these species, artificial regeneration is also one of the effecticve tools.

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Appendix 1. Structural attributes of vegetation in the study sites of Kerala

Sl. No.	Species	Density (No./ha)	Frequency	Basal area (m^2)	IVI
1	*Acacia horida*	0.09	0.014	0.644	0.155
2	*Acacia auriculiformis*	0.33	0.009	0.718	0.210
3	*Achras sapota*	0.13	0.023	0.905	0.241
4	*Acrocarpus fraxinifolius*	0.07	0.014	0.469	0.139
5	*Actinodaphne madraspatana*	1.43	0.060	2.943	1.030
6	*Aglaia apiocarpa*	0.06	0.005	0.344	0.067
7	*Aglaia barberi*	0.59	0.046	4.838	0.754
8	*Aglaia malabarica*	0.73	0.050	2.942	0.733
9	*Agrostistachys borneensis*	0.40	0.032	2.514	0.479
10	*Agrostistachys bunius*	0.02	0.005	0.028	0.038
11	*Agrostistachys longifolia*	0.02	0.005	0.036	0.038
12	*Ailanthus excelsa*	0.02	0.005	0.076	0.040
13	*Ailanthus triphysa*	3.98	0.032	6.912	1.925
14	*Albizia lebbeck*	0.88	0.106	4.242	1.211
15	*Albizia odoratissima*	0.97	0.161	8.512	1.826
16	*Albizia procera*	0.17	0.032	2.105	0.377
17	*Alseodaphne semecarpifolia*	0.42	0.032	1.226	0.417
18	*Alstonia scholaris*	1.25	0.170	7.975	1.951
19	*Anacardium occidentale*	0.06	0.005	0.110	0.054
20	*Anacolosa densiflora*	0.11	0.018	0.604	0.189
21	*Anogeissus acuminata*	0.02	0.005	0.025	0.037
22	*Anogeissus latifolia*	4.06	0.110	14.547	2.862
23	*Antiaris toxicaria*	0.06	0.005	1.768	0.142
24	*Antidesma alexiteria*	0.02	0.005	0.396	0.057
25	*Antidesma diandrum*	0.02	0.005	0.016	0.037
26	*Antidesma lindleyana*	0.73	0.041	2.725	0.662
27	*Aporosa acuminata*	0.04	0.005	0.016	0.043
28	*Aporusa lindleyana*	5.83	0.307	14.027	4.724
29	*Aralia malabarica*	0.02	0.005	0.074	0.040
30	*Archidendron vigenminum*	0.02	0.005	0.036	0.038
31	*Aristolochia tagala*	0.13	0.005	0.442	0.097
32	*Artocarpus heterophyllus*	0.44	0.032	3.014	0.518
33	*Artocarpus hirsutus*	2.31	0.179	17.525	2.877
34	*Atalantia racemosa*	0.11	0.014	0.173	0.136
35	*Atuna travancorica*	0.04	0.009	0.113	0.078
36	*Azadirachta indica*	0.06	0.005	0.095	0.054
37	*Baccaurea courtallensis*	0.28	0.046	0.565	0.422
38	*Bauchanania axillaris*	0.18	0.009	0.647	0.156
39	*Bauhinia malabarica*	0.77	0.106	3.602	1.140
40	*Bischofia javanica*	0.33	0.041	1.622	0.467
41	*Bixa orellana*	0.04	0.005	0.074	0.046
42	*Bombax ceiba*	1.45	0.188	9.242	2.206
43	*Bombax malabaricum*	0.68	0.050	4.394	0.791
44	*Boswellia serrata*	0.04	0.005	0.246	0.055
45	*Briedelia retusa*	1.50	0.206	14.141	2.603
46	*Buchanania axillaris*	0.24	0.028	1.954	0.364
47	*Buchanania lanzan*	0.06	0.009	0.262	0.092
48	*Butea monosperma*	0.26	0.028	1.038	0.321
49	*Callicarpa tomentosa*	0.31	0.050	1.252	0.501
50	*Calophyllum austroindicum*	0.02	0.005	0.018	0.037
51	*calophyllum elatum*	0.02	0.005	0.513	0.063
52	*Calophyllum inophyllum*	4.50	0.211	27.540	4.355
53	*Calophyllum polyanthum*	1.17	0.073	12.841	1.555

54	*Canarium strictum*	0.11	0.023	0.408	0.209
55	*Canthium angustiifolium*	0.04	0.005	0.030	0.044
56	*Careya arborea*	3.96	0.275	10.889	3.714
57	*Caryota urens*	0.18	0.023	0.616	0.244
58	*Cassia fistula*	2.09	0.220	7.775	2.556
59	*Catunaregam spinosa*	0.02	0.005	0.055	0.039
60	*Celtis* sp.	0.09	0.005	0.234	0.073
61	*Chionanthus courtallensis*	0.07	0.018	0.221	0.156
62	*Chionanthus mala-elengi*	0.11	0.014	0.383	0.147
63	*Chukrasia tabularis*	0.07	0.014	0.882	0.161
64	*Cinnamomum malabatrum*	0.70	0.119	2.277	1.134
65	*Cipadessa baccifera*	0.07	0.009	0.083	0.089
66	*Clausena anisata*	0.06	0.009	0.214	0.090
67	*Cleistanthus collinus*	1.19	0.041	4.305	0.901
68	*Croton malabaricus*	0.04	0.005	0.048	0.045
69	*Cullenia exarillata*	0.15	0.023	2.239	0.318
70	*Dalbergia lanceolaria*	1.19	0.073	8.191	1.316
71	*Dalbergia latifolia*	4.70	0.404	27.791	5.694
72	*Dalbergia sissoides*	0.53	0.069	6.467	0.971
73	*Delonix regia*	0.02	0.005	0.011	0.037
74	*Dendrocnide sinuata*	0.02	0.005	0.011	0.037
75	*Dillenia pentagyna*	3.60	0.252	27.933	4.341
76	*Dimocarpus longan*	0.28	0.023	1.022	0.297
77	*Diospyros affinis*	0.29	0.032	0.604	0.341
78	*Diospyros bourdillonii*	0.37	0.023	2.174	0.389
79	*Diospyros candolleana*	0.13	0.032	1.047	0.308
80	*Diospyros cordifolia*	0.18	0.028	1.853	0.340
81	*Diospyros ovalifolia*	0.28	0.028	1.318	0.342
82	*Diospyrous montana*	0.09	0.005	1.587	0.145
83	*Dipterocarpus bourdillonii*	0.79	0.037	8.940	0.979
84	*Drypetes elata*	0.51	0.023	3.245	0.495
85	*Drypetes oblongifolia*	0.04	0.009	0.112	0.078
86	*Dysoxylum beddomei*	0.15	0.014	0.561	0.169
87	*Dysoxylum malabaricum*	0.72	0.064	9.646	1.171
88	*Ehretia pubscens*	0.02	0.005	0.509	0.063
89	*Elaeocarpus serratus*	0.28	0.041	4.245	0.587
90	*Elaeocarpus tuberculatus*	0.20	0.014	3.033	0.318
91	*Elaeocarpus variabilis*	0.68	0.069	1.122	0.738
92	*Ensete superbum*	0.09	0.005	1.577	0.144
93	*Erythrina stricta*	0.13	0.023	0.810	0.236
94	*Erythrina variegata*	0.64	0.096	3.768	1.045
95	*Erythroxylum monogynum*	0.02	0.005	0.011	0.037
96	*Erythroxylum moonii*	0.02	0.005	0.025	0.037
97	*Eucalyptus globulus*	0.24	0.014	0.305	0.187
98	*Euphorbia anticuorum*	0.07	0.005	0.291	0.070
99	*Fahrenheitia zeylanica*	0.06	0.014	0.246	0.121
100	*Ficus arnottiana*	0.02	0.005	0.015	0.037
101	*Ficus benghalensis*	0.04	0.009	0.798	0.114
102	*Ficus dalhousiae*	0.02	0.005	0.497	0.062
103	*Ficus drupacea*	0.07	0.014	1.046	0.170
104	*Ficus exasperata*	0.09	0.009	0.576	0.121
105	*Ficus heterophyllus*	0.04	0.009	0.077	0.076
106	*Ficus hispida*	0.55	0.069	2.678	0.777
107	*Ficus nervosa*	0.04	0.005	0.165	0.051
108	*Ficus racemosa*	0.07	0.018	0.964	0.196
109	*Ficus religiosa*	0.17	0.028	4.036	0.449

110	*Flacourtia indica*	0.09	0.005	0.109	0.067
111	*Flacourtia montana*	0.50	0.041	1.174	0.499
112	*Garcinia gummi-gutta*	0.11	0.023	0.647	0.221
113	*Garua pinnata*	0.02	0.005	0.078	0.040
114	*Gliricidia sepium*	0.02	0.005	0.064	0.040
115	*Glochidion malabaricum*	0.04	0.005	0.150	0.050
116	*Gmelina arborea*	1.05	0.188	7.619	1.984
117	*Gnidia glauca*	0.02	0.005	0.052	0.039
118	*Gordonia obtusa*	0.02	0.005	0.011	0.037
119	*Grevillea robusta*	0.11	0.009	0.116	0.103
120	*Grewia laevigata*	0.02	0.005	0.226	0.048
121	*Grewia nervosa*	0.02	0.005	0.156	0.044
122	*Grewia tiliifolia*	8.90	0.417	47.232	8.235
123	*Gyrocarpus asiaticus*	0.02	0.005	0.044	0.038
124	*Haldina cordifolia*	1.10	0.133	5.267	1.519
125	*Harpullia arborea*	0.11	0.009	0.673	0.133
126	*Helictrus isora*	0.02	0.005	0.011	0.037
127	*Heptapleurum wallichianum*	0.02	0.005	0.037	0.038
128	*Holarrhena pubescens*	0.70	0.092	2.881	0.987
129	*Holigarna arnottiana*	0.06	0.009	0.450	0.102
130	*Holigarna beddomei*	0.24	0.032	1.094	0.348
131	*Holigarna grahamii*	0.09	0.014	0.076	0.125
132	*Holigarna nigra*	0.79	0.041	3.976	0.747
133	*Holigarna peltata*	0.02	0.005	0.023	0.037
134	*Holoptelea integrifolia*	0.55	0.087	4.016	0.967
135	*Homonoia rapiria*	0.02	0.005	0.013	0.037
136	*Hopea parviflora*	0.94	0.050	15.470	1.464
137	*Hopea ponga*	0.02	0.005	0.017	0.037
138	*Hopea racophloea*	0.15	0.009	0.121	0.116
139	*Hydnocarpus alpina*	0.04	0.005	0.107	0.048
140	*Hydnocarpus macrocarpa*	0.20	0.009	1.084	0.186
141	*Hydnocarpus pentandra*	1.17	0.115	11.805	1.770
142	*Hymenodictyon excelsum*	0.15	0.014	0.547	0.168
143	*Isonandra perrottetiana*	0.02	0.005	0.051	0.039
144	*Ixora brachiata*	0.07	0.014	0.063	0.118
145	*Jatropha gossypifolia*	0.04	0.005	0.130	0.049
146	*Kingiodendron pinnatum*	0.11	0.009	1.211	0.161
147	*Knema attenuata*	0.26	0.032	2.120	0.409
148	*Kydia calycina*	0.29	0.046	1.377	0.471
149	*Lagerstroemia flos-reginae*	1.10	0.037	9.961	1.139
150	*Lagerstroemia microcarpa*	8.00	0.518	83.510	10.505
151	*Lannea coromandelica*	1.34	0.142	4.731	1.632
152	*Lea indica*	0.09	0.009	0.065	0.094
153	*Lepisanthes senegalensis*	0.06	0.005	0.064	0.052
154	*Lepisanthes tetraphyllus*	0.09	0.014	1.013	0.174
155	*Litsea beddomei*	2.02	0.133	5.372	1.836
156	*Litsea wightiana*	0.02	0.005	0.012	0.037
157	*Lophopetalum wightianum*	0.02	0.005	0.012	0.037
158	*Macaranga peltata*	7.16	0.408	24.549	6.386
159	*Madhuca longifolia*	0.42	0.018	2.698	0.405
160	*Mallotus philippensis*	1.39	0.197	5.104	2.029
161	*Mallotus tetracoccus*	0.02	0.005	0.012	0.070
162	*Mangifera indica*	0.13	0.028	1.276	0.291
163	*Manilkara hexandra*	0.04	0.005	0.030	0.044
164	*Mastixia arborea*	0.07	0.005	0.531	0.083
165	*Melia dubia*	0.17	0.023	1.941	0.308

166	*Melicope lunu-ankenda*	1.39	0.115	4.821	1.475
167	*Memecylon deccanense*	0.04	0.005	0.029	0.044
168	*Memecylon umbellatum*	0.17	0.028	1.020	0.289
169	*Mesua ferrea*	0.37	0.032	0.875	0.380
170	*Miliusa tomentosa*	2.00	0.174	9.131	2.297
171	*Mimusops elengi*	0.09	0.014	0.552	0.150
172	*Mitragyna parvifolia*	0.97	0.087	5.283	1.177
173	*Mitrephora heyneana*	0.15	0.005	0.653	0.114
174	*Morinda coriea*	0.02	0.005	0.012	0.038
175	*Myristica attenuata*	0.61	0.037	2.546	0.579
176	*Myristica beddomei*	0.06	0.005	0.232	0.061
177	*Myristica malabarica*	0.29	0.037	1.592	0.423
178	*Naringi crenulata*	0.61	0.046	0.938	0.554
179	*Neolamarckia cadamba*	0.13	0.018	0.265	0.177
180	*Neolitsea cassia*	0.04	0.005	0.222	0.054
181	*Neonauclea purpurea*	0.07	0.014	0.320	0.132
182	*Nothapodytes nimmoniana*	0.02	0.005	0.012	0.039
183	*Nothopegia colebrookeana*	0.13	0.014	0.728	0.172
184	*Olea dioica*	3.96	0.248	10.013	3.488
185	*Oroxylum indicum*	0.02	0.005	0.012	0.039
186	*Otonephelium stipulaceum*	0.04	0.009	0.037	0.074
187	*Palaquium ellipticum*	1.25	0.078	7.542	1.330
188	*Palaquium ravii*	0.26	0.023	3.193	0.405
189	*Pavetta indica*	0.40	0.028	0.756	0.356
190	*Persea macrantha*	1.08	0.133	10.127	1.770
191	*Phyllanthus emblica*	3.03	0.229	6.010	2.840
192	*Pithecellobium samman*	0.04	0.009	0.805	0.115
193	*Pleiospermium alatum*	0.04	0.005	0.029	0.044
194	*Polyalthia coffeoides*	0.02	0.005	0.012	0.037
195	*Polyalthia fragrans*	1.38	0.096	5.956	1.410
196	*Pongamia pinnata*	0.17	0.009	0.378	0.136
197	*Premna tomentosa*	0.04	0.005	0.225	0.054
198	*Premna wightiana*	0.11	0.009	0.340	0.115
199	*Psydrax dicoccos*	0.07	0.005	0.158	0.063
200	*Psydrax umbellata*	0.02	0.005	0.012	0.039
201	*Pterocarpus marsupium*	7.14	0.436	60.731	8.471
202	*Pterygota alata*	0.04	0.005	0.375	0.062
203	*Radermachera xylocarpa*	0.06	0.009	0.221	0.090
204	*Randia gardneri*	0.68	0.060	2.062	0.728
205	*Rapanea thwaitesii*	0.09	0.009	0.079	0.095
206	*Reinwardtiodendron anamalaiense*	0.17	0.014	1.579	0.229
207	*Samadera indica*	0.02	0.005	0.012	0.038
208	*Santalum album*	1.32	0.037	1.468	0.765
209	*Sapindus laurifolia*	0.17	0.028	0.835	0.280
210	*Sapindus trifoliata*	0.22	0.046	0.583	0.405
211	*Schefflera wallichiana*	0.02	0.005	0.012	0.037
212	*Schleichera oleosa*	4.44	0.349	32.182	5.479
213	*Scolopia crenata*	0.04	0.009	0.062	0.076
214	*Shorea roxburghii*	0.13	0.018	0.336	0.181
215	*Spondias pinnata*	0.55	0.110	3.340	1.081
216	*Sterculia balanghas*	0.04	0.009	0.111	0.078
217	*Sterculia foetida*	0.02	0.005	0.012	0.039
218	*Sterculia guttata*	0.66	0.083	2.696	0.905
219	*Sterculia urens*	0.13	0.023	0.343	0.211
220	*Sterculia villosa*	0.31	0.050	1.165	0.496
221	*Stereospermum colais*	4.62	0.390	31.903	5.796

222	*Strychnos nux-vomica*	2.26	0.193	11.359	2.622
223	*Strychnos potatorum*	0.06	0.005	0.366	0.068
224	*Swietenia macrophylla*	0.07	0.009	1.002	0.138
225	*Swietenia mahagoni*	1.52	0.055	6.276	1.207
226	*Symplocos cochinchinensis*	0.04	0.009	0.041	0.074
227	*Symplocos racemosa*	0.02	0.005	0.012	0.040
228	*Syzygium caryophyllatum*	0.79	0.050	3.499	0.781
229	*Syzygium cumini*	0.73	0.083	8.545	1.239
230	*Syzygium gardneri*	0.04	0.009	0.329	0.090
231	*Syzygium mundagam*	0.48	0.037	6.400	0.739
232	*Tabernaemontana heyneana*	3.67	0.298	5.972	3.504
233	*Tamarindus indica*	0.07	0.018	0.432	0.167
234	*Tectona grandis*	11.10	0.303	69.376	9.404
235	*Terminalia arjuna*	0.09	0.018	1.628	0.237
236	*Terminalia bellerica*	3.80	0.381	49.693	6.396
237	*Terminalia chebula*	0.79	0.060	10.258	1.198
238	*Terminalia crenulata*	19.01	0.472	179.884	19.031
239	*Terminalia paniculata*	67.14	0.780	497.151	54.118
240	*Terminalia travancorensis*	0.46	0.023	13.080	0.996
241	*Tetrameles nudiflora*	0.59	0.087	16.595	1.644
242	*Toona ciliata*	0.18	0.032	1.632	0.358
243	*Trema orientalis*	0.09	0.005	0.071	0.065
244	*Trewia nudiflora*	0.06	0.009	0.215	0.090
245	*Trichilia connaroides*	0.02	0.005	0.008	0.037
246	*Turpinia malabarica*	0.15	0.009	1.786	0.204
247	*Vateria indica*	1.12	0.069	7.301	1.214
248	*Vepris bilocularis*	0.35	0.046	2.053	0.526
249	*Vernonia arborea*	0.26	0.028	0.909	0.315
250	*Vitex altissima*	0.88	0.119	12.040	1.712
251	*Vitex negundo*	0.02	0.005	0.062	0.039
252	*Wrightia tinctoria*	4.97	0.266	13.774	4.149
253	*Xanthophyllum arnottianum*	0.09	0.023	0.132	0.188
254	*Xanthophyllum flavescens*	0.62	0.032	0.713	0.459
255	*Xanthophyllum rhetza*	0.02	0.005	0.047	0.039
256	*Xantolis tomentosa*	0.11	0.009	0.111	0.103
257	*Xylia xylocarpa*	28.94	0.431	158.564	21.001
258	*Zanthoxylum rhetsa*	0.09	0.018	0.542	0.179
259	*Zizyphus mauritiana*	0.11	0.028	0.324	0.234

Appendix 2. Structural status of vegetation in Northern Forest Circle of Kerala

Sl. No.	Species	Density (No./ha)	Frequency	Basal area (m^2)	IVI
1	*Actinodaphne madraspatana*	6.63	0.132	1.880	4.327
2	*Aglaia barberi*	0.84	0.079	0.798	1.207
3	*Aglaia malabarica*	0.84	0.132	0.895	1.617
4	*Agrostistachys bunius*	0.11	0.026	0.028	0.239
5	*Ailanthus triphysa*	2.32	0.053	0.892	1.650
6	*Albizia lebbeck*	0.11	0.026	0.032	0.241
7	*Albizia odoratissima*	1.26	0.184	1.319	2.323
8	*Alstonia scholaris*	1.16	0.132	0.497	1.589
9	*Anacolosa densiflora*	0.32	0.026	0.150	0.372
10	*Anogeissus latifolia*	6.00	0.079	4.043	4.541
11	*Antidesma lindleyana*	0.95	0.079	0.189	1.013
12	*Aporusa lindleyana*	2.84	0.237	1.325	3.333
13	*Archidendron vigenminum*	0.11	0.026	0.036	0.243

14	*Artocarpus heterophyllus*	0.63	0.053	1.033	1.027
15	*Artocarpus hirsutus*	2.00	0.237	4.299	4.149
16	*Atalantia racemosa*	0.32	0.026	0.113	0.357
17	*Baccaurea courtallensis*	0.21	0.053	0.071	0.485
18	*Bauchanania axillaris*	1.05	0.053	0.647	1.047
19	*Bauhinia malabarica*	0.32	0.053	0.126	0.549
20	*Bischofia javanica*	1.16	0.105	0.717	1.489
21	*Bixa orellana*	0.21	0.026	0.074	0.300
22	*Bombax ceiba*	0.95	0.158	0.867	1.835
23	*Briedelia retusa*	0.42	0.026	2.009	1.136
24	*Butea monosperma*	0.21	0.026	0.083	0.303
25	*Calophyllum austroindicum*	0.11	0.026	0.018	0.236
26	*Calophyllum inophyllum*	0.84	0.184	1.597	2.262
27	*Careya arborea*	2.00	0.184	0.631	2.353
28	*Caryota urens*	0.42	0.026	0.094	0.392
29	*Cassia fistula*	0.84	0.105	0.189	1.157
30	*Cinnamomum malabatrum*	0.63	0.105	0.711	1.275
31	*Clerodendron viscosum*	0.11	0.026	0.018	0.235
32	*Dalbergia lanceolaria*	0.32	0.026	0.107	0.355
33	*Dalbergia latifolia*	7.37	0.500	6.643	9.080
34	*Dalbergia sissoides*	0.42	0.053	0.391	0.693
35	*Dillenia pentagyna*	2.53	0.211	2.577	3.506
36	*Diospyros affinis*	0.32	0.053	0.221	0.585
37	*Diospyros candolleana*	0.32	0.079	0.651	0.939
38	*Dipterocarpus bourdillonii*	1.26	0.079	1.068	1.481
39	*Drypetes elata*	2.95	0.132	3.245	3.376
40	*Dysoxylum malabaricum*	1.26	0.105	1.412	1.801
41	*Elaeocarpus serratus*	0.21	0.026	0.310	0.391
42	*Elaeocarpus variabilis*	2.11	0.158	0.570	2.185
43	*Ensete superbum*	0.53	0.026	1.577	1.010
44	*Erythrina stricta*	0.63	0.105	0.720	1.279
45	*Erythrina variegata*	0.21	0.053	0.078	0.487
46	*Erythroxylum moonii*	0.11	0.026	0.025	0.238
47	*Eucalyptus globulus*	0.11	0.026	0.039	0.244
48	*Ficus arnottiana*	0.11	0.026	0.015	0.234
49	*Ficus drupacea*	0.11	0.026	0.165	0.293
50	*Ficus hispida*	0.32	0.053	0.121	0.546
51	*Ficus racemosa*	0.21	0.053	0.864	0.793
52	*Flacourtia montana*	1.16	0.105	0.624	1.453
53	*Gliricidia sepium*	0.11	0.026	0.064	0.253
54	*Gmelina arborea*	1.26	0.263	0.950	2.739
55	*Grevillea robusta*	0.53	0.026	0.096	0.435
56	*Grewia laevigata*	0.11	0.026	0.226	0.316
57	*Grewia nervosa*	0.11	0.026	0.156	0.289
58	*Grewia tiliifolia*	7.47	0.368	7.758	8.624
59	*Haldina cordifolia*	2.53	0.184	1.421	2.871
60	*Harpullia arborea*	0.11	0.026	0.421	0.392
61	*Helictrus isora*	0.11	0.026	0.011	0.233
62	*Heptapleurum wallichianum*	0.11	0.026	0.037	0.243
63	*Holarrhena pubescens*	0.42	0.053	0.061	0.565
64	*Holigarna arnottiana*	0.32	0.053	0.450	0.674
65	*Holigarna beddomei*	1.05	0.105	0.722	1.449
66	*Hopea parviflora*	3.05	0.079	5.885	4.071
67	*Hydnocarpus pentandra*	0.21	0.053	0.040	0.473
68	*Jatropha gossypifolia*	0.21	0.026	0.130	0.321
69	*Kingiodendron pinnatum*	0.21	0.026	0.445	0.444

70	*Kydia calycina*	0.63	0.079	0.299	0.929
71	*Lagerstroemia microcarpa*	8.00	0.500	12.383	11.563
72	*Lannea coromandelica*	0.53	0.079	0.246	0.866
73	*Lepisanthes tetraphyllus*	0.42	0.053	0.574	0.765
74	*Macaranga peltata*	2.00	0.237	0.877	2.821
75	*Mallotus philippensis*	0.95	0.211	0.382	2.019
76	*Mallotus tetracoccus*	0.11	0.026	0.646	0.480
77	*Mangifera indica*	0.42	0.105	0.778	1.216
78	*Melia dubia*	0.42	0.053	0.174	0.609
79	*Melicope lunu-ankenda*	2.11	0.132	1.503	2.361
80	*Memecylon umbellatum*	0.84	0.132	1.000	1.658
81	*Mitragyna parvifolia*	0.11	0.026	0.069	0.255
82	*Myristica attenuata*	2.53	0.105	1.546	2.361
83	*Naringi crenulata*	0.63	0.053	0.164	0.690
84	*Neolamarckia cadamba*	0.11	0.026	0.076	0.258
85	*Neolitsea cassia*	0.21	0.026	0.222	0.357
86	*Nothapodytes nimmoniana*	0.11	0.026	0.056	0.250
87	*Nothopegia colebrookeana*	0.32	0.026	0.310	0.412
88	*Olea dioica*	15.47	0.605	7.209	13.303
89	*Otonephelium stipulaceum*	0.11	0.026	0.015	0.234
90	*Palaquium ellipticum*	0.84	0.132	0.810	1.584
91	*Persea macrantha*	0.42	0.105	0.530	1.120
92	*Phyllanthus emblica*	2.32	0.237	0.748	2.898
93	*Polyalthia fragrans*	1.79	0.079	1.502	1.861
94	*Pterocarpus marsupium*	4.32	0.421	8.034	7.834
95	*Sapindus trifoliata*	0.53	0.105	0.202	1.035
96	*Schefflera wallichiana*	0.11	0.026	0.023	0.238
97	*Schleichera oleosa*	6.95	0.474	4.895	8.046
98	*Scolopia crenata*	0.21	0.053	0.062	0.481
99	*Spondias pinnata*	0.74	0.184	0.409	1.759
100	*Sterculia guttata*	2.00	0.132	1.214	2.207
101	*Stereospermum colais*	3.58	0.316	3.860	5.172
102	*Strychnos nux-vomica*	3.16	0.158	2.395	3.317
103	*Swietenia mahagoni*	0.21	0.026	0.087	0.305
104	*Symplocos cochinchinensis*	0.11	0.026	0.018	0.235
105	*Symplocos racemosa*	0.11	0.026	0.079	0.259
106	*Syzygium caryophyllatum*	2.63	0.079	0.759	1.912
107	*Syzygium cumini*	0.53	0.079	0.935	1.133
108	*Syzygium gardneri*	0.11	0.026	0.041	0.245
109	*Tabernaemontana heyneana*	0.84	0.158	0.548	1.669
110	*Tectona grandis*	4.42	0.184	8.331	6.316
111	*Terminalia bellerica*	5.79	0.447	12.042	10.169
112	*Terminalia crenulata*	36.11	0.526	56.980	40.365
113	*Terminalia paniculata*	30.00	0.579	32.066	28.609
114	*Tetrameles nudiflora*	0.11	0.026	0.867	0.565
115	*Trewia nudiflora*	0.11	0.026	0.064	0.254
116	*Vateria indica*	2.53	0.105	2.515	2.737
117	*Vitex altissima*	1.37	0.132	5.864	3.758
118	*Vitex negundo*	0.11	0.026	0.062	0.252
119	*Wrightia tinctoria*	0.84	0.105	0.206	1.164
120	*Xanthophyllum arnottianum*	0.32	0.079	0.080	0.717
121	*Xantolis tomentosa*	0.42	0.026	0.057	0.378
122	*Xylia xylocarpa*	22.11	0.421	16.276	18.187
123	*Zanthoxylum rhetsa*	0.11	0.026	0.038	0.243
124	*Zizyphus mauritiana*	0.11	0.026	0.009	0.232

Appendix 3. Structural status of vegetation in Olavakkode Forest Circle of Kerala

Sl. No.	Species	Density (No./ha)	Frequency	Basal area (m^2)	IVI
1	*Acacia auriculiformis*	0.40	0.021	0.129	0.368
2	*Acrocarpus fraxinifolius*	0.11	0.043	0.355	0.415
3	*Actinodaphne madraspatana*	0.17	0.043	0.321	0.436
4	*Aglaia barberi*	1.02	0.064	2.994	1.552
5	*Agrostistachys longifolia*	0.06	0.021	0.036	0.179
6	*Ailanthus excelsa*	0.06	0.021	0.076	0.187
7	*Albizia lebbeck*	0.45	0.128	0.822	1.251
8	*Albizia odoratissima*	0.74	0.191	1.771	2.015
9	*Albizia procera*	0.17	0.064	0.129	0.540
10	*Alstonia scholaris*	0.51	0.128	4.148	1.958
11	*Anacardium occidentale*	0.17	0.021	0.110	0.250
12	*Anogeissus latifolia*	0.62	0.128	1.099	1.394
13	*Antidesma diandrum*	0.06	0.021	0.016	0.175
14	*Antidesma lindleyana*	0.45	0.064	1.119	0.884
15	*Aporosa acuminata*	0.11	0.021	0.016	0.203
16	*Aporusa lindleyana*	0.45	0.106	0.202	0.982
17	*Aristolochia tagala*	0.40	0.021	0.442	0.432
18	*Artocarpus heterophyllus*	0.06	0.021	0.076	0.187
19	*Artocarpus hirsutus*	0.91	0.085	1.480	1.328
20	*Azadirachta indica*	0.17	0.021	0.095	0.248
21	*Baccaurea courtallensis*	0.06	0.021	0.041	0.180
22	*Bauhinia malabarica*	1.87	0.340	3.141	3.863
23	*Bischofia javanica*	0.06	0.021	0.048	0.181
24	*Bombax ceiba*	0.62	0.106	2.459	1.528
25	*Bombax malabaricum*	0.34	0.085	0.203	0.783
26	*Boswellia serrata*	0.11	0.021	0.246	0.250
27	*Briedelia retusa*	0.74	0.191	1.365	1.933
28	*Buchanania axillaris*	0.28	0.085	0.993	0.916
29	*Butea monosperma*	0.17	0.064	0.532	0.622
30	*Callicarpa tomentosa*	0.17	0.064	0.862	0.689
31	*Calophyllum elatum*	0.06	0.021	0.513	0.276
32	*Calophyllum inophyllum*	0.85	0.128	3.954	2.090
33	*Calophyllum polyanthum*	0.85	0.085	1.914	1.388
34	*Canarium strictum*	0.11	0.043	0.105	0.364
35	*Careya arborea*	1.02	0.255	0.911	2.410
36	*Cassia fistula*	1.76	0.213	1.320	2.579
37	*Chukrasia tabularis*	0.06	0.021	0.158	0.204
38	*Cinnamomum malabatrum*	0.34	0.106	0.197	0.924
39	*Cleistanthus collinus*	2.84	0.106	1.671	2.478
40	*Clerodendron infortunatum*	0.06	0.021	0.014	0.174
41	*Clerodendron viscosum*	0.51	0.043	0.127	0.567
42	*Croton malabaricus*	0.11	0.021	0.048	0.210
43	*Cullenia exarillata*	0.40	0.085	2.151	1.209
44	*Dalbergia lanceolaria*	2.38	0.106	6.053	3.144
45	*Dalbergia latifolia*	4.37	0.511	7.168	7.079
46	*Dalbergia sissoides*	0.62	0.106	3.917	1.826
47	*Dillenia pentagyna*	3.01	0.362	8.699	5.709
48	*Diospyros affinis*	0.23	0.043	0.216	0.443
49	*Diospyros bourdillonii*	0.45	0.064	1.109	0.882
50	*Diospyros candolleana*	0.06	0.021	0.163	0.205
51	*Diospyrous montana*	0.28	0.021	1.587	0.609
52	*Dipterocarpus bourdillonii*	0.28	0.021	0.124	0.311
53	*Drypetes oblongifolia*	0.11	0.043	0.112	0.365

54	*Dysoxylum malabaricum*	0.40	0.043	3.174	1.132
55	*Elaeocarpus serratus*	0.40	0.064	0.938	0.819
56	*Erythrina stricta*	0.06	0.021	0.089	0.189
57	*Erythrina variegata*	0.11	0.043	0.963	0.539
58	*Erythroxylum monogynum*	0.06	0.021	0.011	0.174
59	*Eucalyptus globulus*	0.06	0.021	0.100	0.192
60	*Ficus dalhousiae*	0.06	0.021	0.497	0.273
61	*Ficus hispida*	0.23	0.064	0.354	0.614
62	*Ficus nervosa*	0.11	0.021	0.165	0.234
63	*Ficus racemosa*	0.06	0.021	0.024	0.176
64	*Garcinia gummi-gutta*	0.17	0.043	0.307	0.433
65	*Garua pinnata*	0.06	0.021	0.078	0.187
66	*Gmelina arborea*	0.28	0.085	0.520	0.819
67	*Grewia tiliifolia*	6.87	0.511	13.754	9.676
68	*Haldina cordifolia*	0.40	0.149	0.880	1.378
69	*Harpullia arborea*	0.28	0.021	0.252	0.337
70	*Holarrhena pubescens*	0.34	0.128	0.145	1.057
71	*Holigarna nigra*	0.51	0.064	2.531	1.201
72	*Holoptelea integrifolia*	0.62	0.085	1.236	1.136
73	*Hopea parviflora*	0.45	0.021	2.870	0.956
74	*Hydnocarpus macrocarpa*	0.40	0.021	0.190	0.381
75	*Hydnocarpus pentandra*	2.21	0.170	9.031	4.094
76	*knema attenuata*	0.34	0.043	1.153	0.691
77	*Kydia calycina*	0.23	0.043	0.748	0.552
78	*Lagerstroemia flos-reginae*	2.72	0.106	7.339	3.578
79	*Lagerstroemia microcarpa*	6.41	0.596	28.139	12.953
80	*Lannea coromandelica*	0.91	0.021	0.553	0.711
81	*Lepisanthes tetraphyllus*	0.06	0.021	0.439	0.261
82	*Litsea beddomei*	0.11	0.043	0.136	0.370
83	*Macaranga peltata*	1.13	0.191	2.103	2.282
84	*Mallotus philippensis*	0.96	0.149	1.396	1.768
85	*Mangifera indica*	0.06	0.021	0.189	0.210
86	*Melicope lunu-ankenda*	0.28	0.064	0.160	0.603
87	*Memecylon umbellatum*	0.06	0.021	0.020	0.175
88	*Miliusa tomentosa*	1.65	0.255	1.918	2.929
89	*Mimusops elengi*	0.06	0.021	0.048	0.181
90	*Mitragyna parvifolia*	1.13	0.106	2.750	1.844
91	*Myristica beddomei*	0.17	0.021	0.232	0.276
92	*Myristica malabarica*	0.06	0.021	0.086	0.189
93	*Naringi crenulata*	1.30	0.106	0.733	1.518
94	*Neolamarckia cadamba*	0.23	0.043	0.169	0.434
95	*Olea dioica*	0.74	0.191	0.454	1.747
96	*Otonephelium stipulaceum*	0.06	0.021	0.022	0.176
97	*Palaquium ellipticum*	0.11	0.043	0.507	0.446
98	*Palaquium ravii*	0.74	0.085	2.912	1.535
99	*Pavetta indica*	1.19	0.106	0.744	1.463
100	*Persea macrantha*	0.96	0.106	3.521	1.916
101	*Phyllanthus emblica*	1.93	0.234	1.631	2.870
102	*Polyalthia fragrans*	0.06	0.021	0.124	0.197
103	*Pongamia pinnata*	0.17	0.021	0.046	0.238
104	*Premna tomentosa*	0.11	0.021	0.225	0.246
105	*Pterocarpus marsupium*	1.87	0.319	3.819	3.859
106	*Pterygota alata*	0.11	0.021	0.375	0.276
107	*Radermachera xylocarpa*	0.06	0.021	0.050	0.181
108	*Randia gardneri*	0.23	0.064	0.411	0.626
109	*Sapindus laurifolia*	0.23	0.064	0.235	0.590

110	*Schleichera oleosa*	5.62	0.468	16.638	9.352
111	*Spondias pinnata*	0.28	0.064	0.709	0.715
112	*Sterculia guttata*	0.28	0.106	0.231	0.903
113	*Sterculia villosa*	0.06	0.021	0.050	0.182
114	*Stereospermum colais*	4.94	0.468	8.803	7.412
115	*Strychnos nux-vomica*	1.53	0.149	1.886	2.152
116	*Swietenia macrophylla*	0.06	0.021	0.867	0.348
117	*Swietenia mahagoni*	0.06	0.021	0.100	0.192
118	*Syzygium gardneri*	0.06	0.021	0.287	0.230
119	*Syzygium cumini*	0.34	0.106	1.171	1.123
120	*Syzygium mundagam*	0.96	0.106	4.672	2.151
121	*Tabernaemontana heyneyana*	0.17	0.064	0.075	0.529
122	*Tamarindus indica*	0.17	0.064	0.071	0.528
123	*Tectona grandis*	6.58	0.298	13.383	8.031
124	*Terminalia arjuna*	0.11	0.043	0.198	0.383
125	*Terminalia bellerica*	2.21	0.383	7.934	5.297
126	*Terminalia chebula*	0.79	0.085	4.818	1.952
127	*Terminalia crenulata*	17.02	0.596	61.087	25.000
128	*Terminalia paniculata*	39.66	0.872	130.761	52.431
129	*Terminalia travancorensis*	1.02	0.064	8.153	2.604
130	*Tetrameles nudiflora*	0.23	0.064	1.779	0.905
131	*Trewia nudiflora*	0.11	0.021	0.150	0.230
132	*Vateria indica*	0.06	0.021	1.338	0.444
133	*Vepris bilocularis*	0.11	0.021	0.382	0.278
134	*Vitex altissima*	0.34	0.106	0.820	1.052
135	*wrightia tinctoria*	7.26	0.383	7.377	7.718
136	*Xantolis tomentosa*	0.11	0.021	0.054	0.211
137	*xylia xylocarpa*	35.69	0.511	46.986	30.923
138	*Zanthoxylum rhetsa*	0.17	0.043	0.363	0.445
139	*Zizyphus mauritiana*	0.17	0.064	0.026	0.519

Appendix 4. Structural status of vegetation in Central Forest Circle of Kerala

Sl. No.	Species	Density (No./ha)	Frequency	Basal area (m^2)	IVI
1	*Acacia auriculiformis*	0.75	0.026	0.589	0.671
2	*Aglaia barberi*	0.21	0.077	0.856	0.781
3	*Aglaia malabarica*	1.91	0.077	1.535	1.787
4	*Ailanthus triphysa*	0.34	0.051	0.163	0.517
5	*Albizia odoratissima*	0.82	0.231	3.093	2.576
6	*Albizia procera*	0.21	0.051	0.406	0.512
7	*Alstonia scholaris*	1.44	0.231	1.697	2.521
8	*Aporusa lindleyana*	2.60	0.333	3.321	4.118
9	*Artocarpus hirsutus*	0.41	0.128	0.628	1.132
10	*Baccaurea courtallensis*	0.21	0.051	0.220	0.465
11	*Bauhinia malabarica*	0.34	0.103	0.287	0.857
12	*Bombax ceiba*	1.85	0.256	2.501	3.079
13	*Bombax malabaricum*	1.57	0.077	3.261	2.059
14	*Briedelia retusa*	1.37	0.308	2.788	3.228
15	*Callicarpa tomentosa*	0.07	0.026	0.209	0.241
16	*Calophyllum polyanthum*	3.28	0.282	10.442	5.954
17	*Canarium strictum*	0.14	0.051	0.213	0.430
18	*Careya arborea*	0.21	0.051	0.199	0.459
19	*Caryota urens*	0.14	0.026	0.247	0.284
20	*cassia fistula*	0.68	0.205	1.597	1.974
21	*Chionanthus mala-elengi*	0.07	0.026	0.018	0.192

22	*Chukrasia tabularis*	0.21	0.051	0.724	0.593
23	*Cinnamomum malabatrum*	0.14	0.051	0.305	0.453
24	*Cleistanthus collinus*	0.96	0.077	2.627	1.598
25	*Clerodendron viscosum*	0.07	0.026	0.204	0.239
26	*Dalbergia lanceolaria*	0.14	0.051	0.390	0.474
27	*Dalbergia latifolia*	3.28	0.410	6.984	5.846
28	*Delonix regia*	0.07	0.026	0.011	0.191
29	*Dendrocnide sinuata*	0.07	0.026	0.011	0.190
30	*Dillenia pentagyna*	3.97	0.333	10.395	6.584
31	*Dimocarpus longan*	1.03	0.128	1.022	1.532
32	*Diospyros bourdillonii*	0.21	0.026	0.607	0.409
33	*Diospyros ovalifolia*	1.03	0.154	1.318	1.761
34	*Dipterocarpus bourdillonii*	1.78	0.103	7.747	3.455
35	*Dysoxylum beddomei*	0.55	0.077	0.561	0.872
36	*Dysoxylum malabaricum*	0.75	0.128	1.475	1.514
37	*Elaeocarpus serratus*	0.07	0.026	0.084	0.209
38	*Elaeocarpus tuberculatus*	0.14	0.026	0.245	0.283
39	*Erythrina variegata*	0.14	0.051	0.332	0.460
40	*Eucalyptus globulus*	0.75	0.026	0.166	0.563
41	*Fahrenheitia zeylanica*	0.07	0.026	0.009	0.190
42	*Ficus heterophyllus*	0.14	0.051	0.077	0.395
43	*Ficus hispida*	1.57	0.256	2.204	2.871
44	*Ficus religiosa*	0.41	0.077	2.224	1.229
45	*Garcinia gummi-gutta*	0.07	0.026	0.020	0.193
46	*Gmelina arborea*	0.75	0.231	2.199	2.315
47	*Grewia tiliifolia*	7.45	0.564	12.964	10.327
48	*Haldina cordifolia*	0.82	0.154	0.788	1.526
49	*Holarrhena pubescens*	1.78	0.282	2.619	3.231
50	*Holigarna grahamii*	0.27	0.051	0.066	0.459
51	*Holigarna nigra*	2.32	0.154	1.445	2.427
52	*Holigarna peltata*	0.07	0.026	0.023	0.194
53	*Holoptelea integrifolia*	0.48	0.179	0.191	1.362
54	*Hopea parviflora*	0.07	0.026	0.716	0.370
55	*Hopea racophloea*	0.55	0.051	0.121	0.606
56	*Hydnocarpus alpina*	0.14	0.026	0.107	0.248
57	*Hydnocarpus pentandra*	0.27	0.051	1.545	0.835
58	*Hymenodictyon excelsum*	0.07	0.026	0.034	0.196
59	*knema attenuata*	0.41	0.077	0.862	0.882
60	*Kydia calycina*	0.07	0.026	0.179	0.233
61	*Lagerstroemia flos-reginae*	0.82	0.077	2.622	1.530
62	*Lagerstroemia microcarpa*	4.10	0.564	10.238	7.999
63	*Lannea coromandelica*	0.62	0.154	0.738	1.414
64	*Lea indica*	0.27	0.026	0.055	0.302
65	*Litsea beddomei*	0.96	0.179	1.240	1.862
66	*Macaranga peltata*	9.71	0.564	9.617	10.576
67	*Mallotus philippensis*	0.48	0.179	1.615	1.724
68	*Mangifera indica*	0.14	0.026	0.309	0.300
69	*Melia dubia*	0.07	0.026	0.128	0.220
70	*Melicope lunu-ankenda*	0.27	0.026	0.385	0.386
71	*Memecylon deccanense*	0.14	0.026	0.029	0.228
72	*Mesua ferrea*	0.07	0.026	0.010	0.190
73	*Miliusa tomentosa*	3.62	0.333	6.030	5.307
74	*Mimusops elengi*	0.21	0.026	0.046	0.266
75	*Mitragyna parvifolia*	0.07	0.026	0.041	0.198
76	*Myristica malabarica*	0.68	0.128	0.737	1.293
77	*Naringi crenulata*	0.21	0.051	0.027	0.415

78	*Neolamarckia cadamba*	0.14	0.026	0.020	0.226
79	*Neonauclea purpurea*	0.21	0.051	0.126	0.441
80	*Olea dioica*	0.41	0.051	0.076	0.528
81	*Palaquim ravii*	0.07	0.026	0.281	0.259
82	*Palaquium ellipticum*	2.32	0.103	4.514	2.899
83	*Pavetta indica*	0.07	0.026	0.013	0.191
84	*Persea macrantha*	0.21	0.051	0.359	0.500
85	*Phyllanthus emblica*	0.48	0.128	0.462	1.123
86	*Pithecellobium samman*	0.14	0.051	0.805	0.580
87	*Polyalthia coffeoides*	0.07	0.026	0.013	0.191
88	*Polyalthia fragrans*	2.26	0.205	2.383	2.941
89	*Psydrax umbellata*	0.07	0.026	0.054	0.201
90	*Pterocarpus marsupium*	2.26	0.333	6.999	4.887
91	*Randia gardneri*	1.98	0.205	1.513	2.586
92	*Reinwardtiodendron anamalaiense*	0.62	0.077	1.579	1.165
93	*Schleichera oleosa*	1.50	0.333	1.551	3.134
94	*Spondias pinnata*	0.34	0.103	0.645	0.948
95	*Sterculia guttata*	0.21	0.051	0.427	0.517
96	*Sterculia urens*	0.21	0.051	0.246	0.471
97	*Stereospermum colais*	3.69	0.538	10.230	7.643
98	*Strychnos nux-vomica*	2.05	0.333	1.989	3.512
99	*Swietenia mahagoni*	3.15	0.077	5.281	3.340
100	*Syzygium caryophyllatum*	0.55	0.077	0.191	0.778
101	*Syzygium cumini*	1.50	0.103	4.856	2.586
102	*Syzygium mundagam*	0.34	0.026	1.636	0.737
103	*Tabernaemontana heyneyana*	1.03	0.205	0.293	1.809
104	*Tectona grandis*	19.83	0.615	27.162	20.281
105	*Terminalia arjuna*	0.07	0.026	0.013	0.191
106	*Terminalia bellerica*	3.01	0.410	12.885	7.213
107	*Terminalia chebula*	0.07	0.026	0.017	0.192
108	*Terminalia crenulata*	10.26	0.564	22.020	13.997
109	*Terminalia paniculata*	33.23	0.769	73.530	39.535
110	*Terminalia travancorensis*	0.41	0.026	3.482	1.240
111	*Tetrameles nudiflora*	0.68	0.179	4.422	2.538
112	*Vateria indica*	1.50	0.128	2.207	2.067
113	*Vepris bilocularis*	0.96	0.179	1.470	1.921
114	*Wrightia tinctoria*	5.06	0.359	4.700	5.823
115	*Xanthophyllum flavescens*	1.23	0.051	0.342	0.996
116	*Xanthophyllum rhetza*	0.07	0.026	0.047	0.200
117	*Xylia xylocarpa*	28.72	0.718	62.639	34.255

Appendix 5. Structural status of vegetation in Highrange Forest Circle of Kerala

Sl. No.	Species	Density (No./ha)	Frequency	Basal area (m^2)	IVI
1	*Acacia horida*	0.13	0.018	0.391	0.273
2	*Achras sapota*	0.19	0.053	0.040	0.435
3	*Acrocarpus fraxinifolius*	0.13	0.018	0.113	0.199
4	*Actinodaphne madraspatana*	0.13	0.035	0.311	0.366
5	*Aglaia apiocarpa*	0.19	0.018	0.344	0.287
6	*Aglaia barberi*	0.19	0.018	0.189	0.246
7	*Aglaia malabarica*	0.26	0.053	0.512	0.588
8	*Agrostistachys borneensis*	1.21	0.088	2.209	1.676
9	*Ailanthus triphysa*	12.06	0.035	5.845	6.931
10	*Albizia lebbeck*	0.89	0.175	0.974	1.783
11	*Albizia odoratissima*	0.96	0.158	2.259	2.037
12	*Albizia procera*	0.19	0.035	1.571	0.727
13	*Alseodaphne semecarpifolia*	1.47	0.105	1.226	1.638
14	*Alstonia scholaris*	1.66	0.281	1.626	2.969
15	*Anacolosa densiflora*	0.06	0.018	0.088	0.165
16	*Anogeissus latifolia*	7.78	0.158	7.887	6.447
17	*Antidesma alexiteria*	0.06	0.018	0.396	0.247
18	*Aporusa lindleyana*	10.91	0.421	6.546	9.141
19	*Aralia malabarica*	0.06	0.018	0.074	0.161
20	*Artocarpus heterophyllus*	0.06	0.018	0.214	0.198
21	*Artocarpus hirsutus*	2.23	0.228	7.179	4.345
22	*Atalantia racemosa*	0.19	0.035	0.060	0.326
23	*Atuna travancorica*	0.06	0.018	0.100	0.168
24	*Baccaurea courtallensis*	0.26	0.053	0.109	0.481
25	*Bauhinia malabarica*	0.06	0.018	0.047	0.154
26	*Bischofia javanica*	0.26	0.035	0.793	0.548
27	*Bombax ceiba*	1.21	0.211	2.235	2.482
28	*Bombax malabaricum*	0.51	0.070	0.929	0.922
29	*Briedelia retusa*	0.77	0.123	0.482	1.255
30	*Butea monosperma*	0.57	0.035	0.422	0.586
31	*Callicarpa tomentosa*	0.70	0.088	0.161	0.914
32	*Calophyllum inophyllum*	3.57	0.263	6.572	4.985
33	*Calophyllum polyanthum*	0.06	0.018	0.485	0.270
34	*Canarium strictum*	0.13	0.018	0.090	0.193
35	*Canthium angustiifolium*	0.13	0.018	0.030	0.177
36	*Careya arborea*	1.21	0.193	0.512	1.911
37	*Caryota urens*	0.26	0.053	0.276	0.525
38	*Cassia fistula*	1.21	0.175	1.390	2.030
39	*Catunaregam spinosa*	0.06	0.018	0.055	0.156
40	*Celtis* sp.	0.32	0.018	0.234	0.313
41	*Chionanthus courtallensis*	0.26	0.053	0.221	0.511
42	*Chionanthus mala-elengi*	0.32	0.035	0.365	0.462
43	*Cinnamomum malabatrum*	1.02	0.211	0.742	2.004
44	*Cipadessa baccifera*	0.26	0.053	0.083	0.474
45	*Clausena anisata*	0.19	0.035	0.214	0.367
46	*Cleistanthus collinus*	0.06	0.018	0.008	0.144
47	*Cullenia exarillata*	0.06	0.018	0.088	0.165
48	*Dalbergia lanceolaria*	0.77	0.070	1.144	1.088
49	*Dalbergia latifolia*	1.66	0.281	3.802	3.547
50	*Dalbergia sissoides*	0.83	0.123	2.128	1.719
51	*Dillenia pentagyna*	0.57	0.070	1.339	1.058
52	*Diospyros bourdillonii*	0.57	0.018	0.458	0.481
53	*Diospyros candolleana*	0.13	0.018	0.169	0.214

54	*Diospyros cordifolia*	0.64	0.105	1.853	1.450
55	*Dysoxylum malabaricum*	0.57	0.053	3.585	1.540
56	*Ehretia pubscens*	0.06	0.018	0.509	0.277
57	*Elaeocarpus serratus*	0.32	0.070	2.913	1.367
58	*Elaeocarpus tuberculatus*	0.70	0.035	3.154	1.366
59	*Elaeocarpus variabilis*	0.83	0.105	0.497	1.172
60	*Erythrina variegata*	1.59	0.211	2.151	2.624
61	*Euphorbia anticuorum*	0.26	0.035	0.291	0.415
62	*Fahrenheitia zeylanica*	0.06	0.018	0.122	0.174
63	*Ficus benghalensis*	0.13	0.035	0.798	0.495
64	*Ficus drupacea*	0.19	0.035	0.881	0.544
65	*Ficus exasperata*	0.32	0.035	0.576	0.518
66	*Ficus racemosa*	0.06	0.018	0.075	0.162
67	*Ficus religiosa*	0.19	0.053	1.887	0.906
68	*Flacourtia indica*	0.32	0.018	0.109	0.279
69	*Flacourtia montana*	1.02	0.070	0.550	1.039
70	*Garcinia gummi-gutta*	0.13	0.035	0.320	0.368
71	*Glochidion malabaricum*	0.13	0.018	0.150	0.209
72	*Gmelina arborea*	1.02	0.193	1.508	2.093
73	*Gnidia glauca*	0.06	0.018	0.052	0.155
74	*Gordonia obtusa*	0.06	0.018	0.011	0.144
75	*Grevillea robusta*	0.06	0.018	0.020	0.147
76	*Grewia tiliifolia*	2.30	0.298	2.043	3.466
77	*Gyrocarpus asiaticus*	0.06	0.018	0.044	0.153
78	*Haldina cordifolia*	0.38	0.053	0.683	0.688
79	*Holigarna beddomei*	0.06	0.018	0.145	0.180
80	*Holoptelea integrifolia*	0.19	0.053	0.110	0.454
81	*Homonoia rapiria*	0.06	0.018	0.013	0.145
82	*Hopea parviflora*	0.64	0.070	5.954	2.310
83	*Hydnocarpus macrocarpa*	0.26	0.018	0.895	0.461
84	*Hydnocarpus pentandra*	1.02	0.158	1.028	1.738
85	*Hymenodictyon excelsum*	0.45	0.035	0.514	0.556
86	*Isonandra perrottetiana*	0.06	0.018	0.051	0.155
87	*Ixora brachiata*	0.26	0.053	0.063	0.469
88	*Knema attenuata*	0.06	0.018	0.026	0.148
89	*Kydia calycina*	0.32	0.070	0.151	0.634
90	*Lagerstroemia microcarpa*	5.81	0.456	15.231	9.495
91	*Lannea coromandelica*	1.28	0.140	1.029	1.732
92	*Lea indica*	0.06	0.018	0.010	0.144
93	*Lepisanthes senegalensis*	0.19	0.018	0.064	0.213
94	*Litsea beddomei*	2.81	0.193	2.881	3.221
95	*Litsea wightiana*	0.06	0.018	0.012	0.145
96	*Macaranga peltata*	5.17	0.404	6.723	6.621
97	*Madhuca longifolia*	1.28	0.053	2.780	1.626
98	*Mallotus philippensis*	1.59	0.228	1.021	2.438
99	*Manilkara hexandra*	0.13	0.018	0.030	0.177
100	*Mastixia arborea*	0.26	0.018	0.531	0.364
101	*Melicope lunu-ankenda*	2.81	0.228	2.678	3.396
102	*Mesua ferrea*	1.08	0.088	0.731	1.229
103	*Miliusa tomentosa*	0.38	0.070	0.310	0.703
104	*Mimusops elengi*	0.06	0.018	0.458	0.263
105	*Mitragyna parvifolia*	0.83	0.123	0.814	1.370
106	*Mitrephora heyneana*	0.51	0.018	0.653	0.506
107	*Myristica attenuata*	0.32	0.035	0.905	0.605
108	*Myristica malabarica*	0.32	0.035	0.769	0.569
109	*Naringi crenulata*	0.06	0.018	0.014	0.145

110	*Neonauclea purpurea*	0.06	0.018	0.194	0.193
111	*Nothopegia colebrookeana*	0.26	0.035	0.474	0.463
112	*Olea dioica*	2.30	0.211	1.918	2.862
113	*Palaquium ellipticum*	0.19	0.053	1.006	0.692
114	*Persea macrantha*	1.91	0.246	4.086	3.502
115	*Phyllanthus emblica*	1.91	0.193	0.998	2.339
116	*Pleiospermium alatum*	0.13	0.018	0.029	0.177
117	*Polyalthia fragrans*	1.08	0.123	1.032	1.537
118	*Pongamia pinnata*	0.38	0.018	0.332	0.366
119	*Premna wightiana*	0.38	0.035	0.340	0.482
120	*Pterocarpus marsupium*	4.47	0.421	11.528	7.711
121	*Randia gardneri*	0.32	0.035	0.209	0.420
122	*Rapanea thwaitesii*	0.32	0.035	0.079	0.386
123	*Samadera indica*	0.06	0.018	0.036	0.151
124	*Santalum album*	4.59	0.123	1.468	3.152
125	*Sapindus laurifolia*	0.32	0.053	0.600	0.638
126	*Sapindus trifoliata*	0.19	0.035	0.274	0.383
127	*Schleichera oleosa*	2.17	0.281	5.135	4.118
128	*Shorea roxburghii*	0.45	0.070	0.336	0.737
129	*Spondias pinnata*	0.57	0.140	1.129	1.459
130	*Sterculia balanghas*	0.13	0.035	0.111	0.313
131	*Sterculia guttata*	0.57	0.105	0.823	1.150
132	*Sterculia urens*	0.13	0.035	0.044	0.295
133	*Sterculia villosa*	0.57	0.088	0.659	0.992
134	*Stereospermum colais*	4.02	0.456	7.521	6.685
135	*Strychnos nux-vomica*	1.59	0.175	2.235	2.418
136	*Strychnos potatorum*	0.19	0.018	0.366	0.293
137	*Swietenia mahagoni*	0.19	0.035	0.106	0.338
138	*Symplocos cochinchinensis*	0.06	0.018	0.023	0.148
139	*Syzygium caryophyllatum*	0.57	0.070	2.488	1.363
140	*Syzygium cumini*	0.38	0.088	1.572	1.152
141	*Syzygium mundagam*	0.26	0.035	0.092	0.362
142	*Tabernaemontana heyneyana*	4.59	0.404	2.022	5.127
143	*Tamarindus indica*	0.06	0.018	0.361	0.237
144	*Tectona grandis*	7.53	0.211	11.037	7.517
145	*Terminalia arjuna*	0.13	0.018	1.417	0.545
146	*Terminalia bellerica*	2.23	0.263	6.953	4.514
147	*Terminalia chebula*	1.72	0.123	5.383	2.965
148	*Terminalia crenulata*	8.68	0.281	15.379	9.618
149	*Terminalia paniculata*	58.95	0.754	107.235	58.564
150	*Terminalia travancorensis*	0.06	0.018	1.444	0.525
151	*Tetrameles nudiflora*	0.77	0.088	7.935	3.005
152	*Toona ciliata*	0.64	0.140	1.632	1.620
153	*Trichilia connaroides*	0.06	0.018	0.008	0.144
154	*Turpinia malabarica*	0.51	0.035	1.786	0.921
155	*Vateria indica*	0.13	0.018	0.064	0.186
156	*Vepris bilocularis*	0.19	0.035	0.200	0.364
157	*Vernonia arborea*	0.89	0.105	0.909	1.309
158	*Vitex altissima*	0.77	0.140	4.586	2.459
159	*Wrightia tinctoria*	0.89	0.158	0.319	1.495
160	*Xanthophyllum arnottianum*	0.06	0.018	0.014	0.145
161	*Xanthophyllum flavescens*	1.02	0.088	0.371	1.106
162	*Xylia xylocarpa*	14.42	0.351	23.011	14.553
163	*Zizyphus mauritiana*	0.13	0.035	0.290	0.360

Appendix 6. Structural status of vegetation in Southern Forest Circle of Kerala

Sl. No.	Species	Density (No./ha)	Frequency	Basal area (m^2)	IVI
1	*Acacia horida*	0.23	0.029	0.253	0.323
2	*Achras sapota*	0.30	0.057	0.865	0.686
3	*Actinodaphne madraspatana*	0.76	0.114	0.431	1.083
4	*Agrostistachys borneensis*	0.23	0.057	0.306	0.509
5	*Ailanthus triphysa*	0.08	0.029	0.012	0.203
6	*Albizia lebbeck*	1.90	0.171	2.415	2.376
7	*Albizia odoratissima*	0.08	0.029	0.070	0.218
8	*Alstonia scholaris*	0.08	0.029	0.008	0.202
9	*Anacolosa densiflora*	0.15	0.057	0.366	0.497
10	*Anogeissus acuminata*	0.08	0.029	0.025	0.206
11	*Anogeissus latifolia*	2.36	0.143	1.518	2.135
12	*Antiaris toxicaria*	0.23	0.029	1.768	0.726
13	*Antidesma lindleyana*	1.75	0.086	1.417	1.540
14	*Aporusa lindleyana*	5.64	0.457	2.632	5.531
15	*Artocarpus heterophyllus*	1.22	0.086	1.691	1.415
16	*Artocarpus hirsutus*	3.89	0.257	4.064	4.061
17	*Atuna travancorica*	0.08	0.029	0.013	0.203
18	*Baccaurea courtallensis*	0.38	0.057	0.124	0.517
19	*Bischofia javanica*	0.15	0.057	0.065	0.417
20	*Bombax ceiba*	0.99	0.229	1.180	2.052
21	*Briedelia retusa*	2.51	0.457	7.497	5.665
22	*Buchanania axillaris*	0.23	0.029	0.190	0.307
23	*Buchanania lanzan*	0.23	0.057	0.262	0.497
24	*Callicarpa tomentosa*	0.15	0.057	0.020	0.405
25	*Calophyllum inophyllum*	12.65	0.514	15.417	11.863
26	*Careya arborea*	11.96	0.800	8.636	11.525
27	*Cassia fistula*	3.50	0.457	3.279	4.913
28	*Cinnamomum malabatrum*	0.61	0.086	0.321	0.826
29	*Dalbergia lanceolaria*	0.46	0.086	0.498	0.816
30	*Dalbergia latifolia*	2.67	0.371	3.194	4.065
31	*Dalbergia sissoides*	0.08	0.029	0.032	0.208
32	*Dillenia pentagyna*	3.96	0.371	4.923	5.004
33	*Diospyros affinis*	0.69	0.086	0.167	0.813
34	*Diospyros candolleana*	0.08	0.029	0.063	0.216
35	*Elaeocarpus variabilis*	0.30	0.086	0.055	0.642
36	*Erythrina variegata*	0.30	0.086	0.244	0.692
37	*Fahrenheitia zeylanica*	0.08	0.029	0.115	0.230
38	*Gmelina arborea*	0.99	0.200	2.442	2.216
39	*Grewia tiliifolia*	11.28	0.429	10.714	9.593
40	*Haldina cordifolia*	0.84	0.171	1.494	1.736
41	*Holarrhena pubescens*	0.15	0.029	0.055	0.243
42	*Holigarna beddomei*	0.15	0.057	0.226	0.460
43	*Holigarna grahamii*	0.08	0.029	0.009	0.202
44	*Holoptelea integrifolia*	0.69	0.143	2.478	1.769
45	*Hopea parviflora*	0.23	0.057	0.044	0.440
46	*Hopea ponga*	0.08	0.029	0.017	0.204
47	*Hydnocarpus pentandra*	0.30	0.114	0.221	0.858
48	*Kingiodendron pinnatum*	0.30	0.029	0.765	0.487
49	*Knema attenuata*	0.08	0.029	0.080	0.221
50	*Lagerstroemia microcarpa*	7.31	0.514	17.518	10.446
51	*Lannea coromandelica*	1.75	0.371	2.166	3.454
52	*Litsea beddomei*	3.81	0.257	1.115	3.251

53	*Lophopetalum wightianum*	0.08	0.029	0.014	0.203
54	*Macaranga peltata*	9.75	0.743	5.229	9.459
55	*Madhuca longifolia*	0.30	0.029	0.121	0.317
56	*Mallotus philippensis*	1.37	0.229	0.690	2.063
57	*Melia dubia*	0.30	0.057	1.638	0.891
58	*Melicope lunu-ankenda*	0.23	0.086	0.094	0.624
59	*Mesua ferrea*	0.15	0.029	0.134	0.264
60	*Miliusa tomentosa*	1.60	0.257	0.873	2.368
61	*Mitragyna parvifolia*	1.37	0.143	1.609	1.793
62	*Morinda coriea*	0.08	0.029	0.031	0.208
63	*Myristica attenuata*	0.30	0.057	0.095	0.481
64	*Olea dioica*	1.07	0.229	0.357	1.862
65	*Oroxylum indicum*	0.08	0.029	0.048	0.212
66	*Palaquium ellipticum*	1.60	0.086	0.706	1.295
67	*Persea macrantha*	0.38	0.114	1.631	1.260
68	*Phyllanthus emblica*	5.49	0.400	2.171	5.009
69	*Polyalthia fragrans*	0.53	0.057	0.915	0.783
70	*Psydrax dicoccos*	0.30	0.029	0.158	0.326
71	*Pterocarpus marsupium*	16.15	0.743	30.351	18.497
72	*Radermachera xylocarpa*	0.15	0.029	0.171	0.273
73	*Sapindus trifoliata*	0.30	0.114	0.107	0.827
74	*Schleichera oleosa*	1.60	0.200	3.963	2.845
75	*Spondias pinnata*	0.30	0.057	0.447	0.575
76	*Sterculia foetida*	0.08	0.029	0.057	0.215
77	*Sterculia urens*	0.15	0.029	0.053	0.242
78	*Sterculia villosa*	0.53	0.143	0.456	1.176
79	*Stereospermum colais*	1.07	0.114	1.489	1.476
80	*Strychnos nux-vomica*	0.84	0.171	2.853	2.097
81	*Swietenia macrophylla*	0.23	0.029	0.135	0.292
82	*Swietenia mahagoni*	2.36	0.143	0.702	1.919
83	*Syzygium caryophyllatum*	0.08	0.029	0.061	0.216
84	*Syzygium cumini*	0.08	0.029	0.011	0.203
85	*Tabernaemontana heyneyana*	7.85	0.714	3.048	8.004
86	*Tectona grandis*	2.97	0.314	9.463	5.499
87	*Terminalia bellerica*	2.59	0.486	9.880	6.498
88	*Terminalia chebula*	0.08	0.029	0.040	0.210
89	*Terminalia crenulata*	8.15	0.486	24.418	12.416
90	*Terminalia paniculata*	96.69	0.971	154.462	82.635
91	*Tetrameles nudiflora*	0.38	0.086	1.593	1.079
92	*Trema orientalis*	0.38	0.029	0.071	0.331
93	*Vateria indica*	0.91	0.114	1.178	1.337
94	*Vitex altissima*	1.30	0.229	0.769	2.056
95	*Wrightia tinctoria*	3.58	0.371	1.171	3.867
96	*Xanthophyllum arnottianum*	0.08	0.029	0.038	0.210
97	*Xylia xylocarpa*	7.01	0.171	9.653	6.187
98	*Zanthoxylum rhetsa*	0.08	0.029	0.141	0.237

Appendix 7. Regeneration status of *T. paniculata* in Forest Circle of Kerala in terms of density (individuals per ha)

Divisions in each Forest Circle	<3cm collar girth			Total (<3cm collar girth)	3-9.9cm Gbh	10-30cm Gbh
	<50cmht	50-100cmht	>100cmht			
Kannur	21.15	21.54	3.08	45.77	7.31	5.38
AralamWLD	0.00	0.00	0.00	0.00	0.00	0.00
Kozhikkod	0.80	5.60	9.60	16.00	3.20	15.20
Wayanad North	0.00	0.00	0.00	0.00	0.00	2.22
Wayanad South	0.00	0.00	0.00	0.00	0.00	0.00
Wayanad WLD	0.00	0.00	0.00	0.00	0.00	0.00
Northern Circle	**7.94**	**8.94**	**2.84**	**19.72**	**3.26**	**4.82**
Nilambur North	23.53	30.59	12.94	67.06	21.18	6.47
Nilambur South	18.79	24.85	1.21	44.85	21.82	7.27
Mannarghat	1.90	1.90	0.95	4.76	1.90	0.95
Palakkad	5.90	15.08	4.92	25.90	27.21	16.72
Nenmara	12.00	17.00	3.00	32.00	23.00	18.00
Silent Valley NP	0.00	0.00	0.00	0.00	0.00	0.00
Parambikkulam WLD	0.00	0.00	0.51	0.51	0.00	2.05
Olavakkode Circle	**11.39**	**16.73**	**5.26**	**33.39**	**17.21**	**8.61**
Chalakkudi	10.73	24.88	8.78	44.39	47.80	53.66
Malayattoor	2.45	5.71	0.00	8.16	42.45	26.53
Peechi-Vazhani WLD	18.52	25.93	2.22	46.67	76.30	50.37
Thrissur	15.00	8.00	2.00	25.00	8.00	78.00
Vazhachal	0.00	0.00	0.00	0.00	0.00	0.00
Central Circle	**8.83**	**12.34**	**2.66**	**23.83**	**34.15**	**42.45**
Marayoor Sandal	0.00	0.00	0.00	0.00	0.00	0.00
Eravikulam NP	0.00	0.00	0.00	0.00	0.00	0.00
Munnar	1.96	9.80	4.31	16.08	18.04	16.86
Mankulam	1.25	5.00	6.25	12.50	7.50	5.00
Idukki WLD	0.98	10.24	5.85	17.07	16.59	18.54
Thekkadi WLD	1.43	4.29	0.71	6.43	4.29	17.14
Kothamangalam	6.45	28.06	19.68	54.19	19.03	36.45
Kottayam	10.00	29.33	11.33	50.67	12.00	38.00
Highrange Circle	**3.46**	**14.38**	**8.23**	**26.08**	**13.00**	**21.46**
Ranni	13.75	31.25	20.00	65.00	5.00	24.38
Konni	14.29	23.81	13.33	51.43	3.81	8.57
Achancovil	12.12	24.24	9.70	46.06	23.03	26.67
Punalur	24.00	52.00	19.00	95.00	28.00	47.00
Thenmala	27.00	49.00	13.00	89.00	22.00	26.00
Trivandrum	8.33	30.00	14.17	52.50	17.50	43.33
Trivandrum WLD	23.18	31.82	16.82	71.82	31.36	40.00
Southern Circle	**17.42**	**33.20**	**15.26**	**65.88**	**19.59**	**31.44**

Appendix 8. Regeneration status of *T. crenulata* and *T. travancorensis* in Forest Circle of Kerala in terms of density (individuals per ha)

Divisions in each Forest Circle	*T. crenulata*						*T. travancorensis*
	<3cm girth<3cm collar girth			Total (<3cm collar girth)	3-9.9 cm Gbh	10-30 cm Gbh	
	<50cmht	50-100cmht	>100cmht				10-30cm Gbh
Kannur	7.69	8.46	1.92	18.08	0.00	0.00	0.00
AralamWLD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kozhikkod	0.00	0.00	0.00	0.00	0.80	0.80	0.00
Wayanad North	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wayanad South	0.00	27.69	1.54	29.23	1.54	0.00	0.00
Wayanad WLD	1.88	3.13	1.88	6.88	0.63	0.63	0.00
Northern Circle	**3.26**	**6.38**	**1.28**	**10.92**	**0.43**	**0.28**	**0.00**
Nilambur North	30.88	14.71	3.24	48.82	3.24	0.88	0.00
Nilambur South	5.45	4.24	0.00	9.70	2.42	0.61	0.00
Mannarghat	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Palakkad	0.33	0.33	0.33	0.98	1.64	1.31	0.00
Nenmara	1.00	1.00	0.00	2.00	1.00	4.00	0.00
Silent Valley NP	2.22	0.00	0.00	2.22	0.00	6.67	0.00
Parambikkulam WLD	0.00	0.00	0.00	0.00	0.00	0.00	0.51
Olavakkode Circle	**9.32**	**4.70**	**0.96**	**14.98**	**1.67**	**1.20**	**0.08**
Chalakkudi	11.22	12.68	3.41	27.32	13.66	0.49	0.00
Malayattoor	0.00	2.45	0.82	3.27	47.35	13.88	0.00
Peechi-Vazhani WLD	11.11	17.04	1.48	29.63	24.44	9.63	0.00
Thrissur	2.50	1.50	0.00	4.00	4.50	29.00	0.00
Vazhachal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Central Circle	**4.57**	**6.17**	**1.17**	**11.91**	**19.79**	**11.28**	**0.00**
Marayoor Sandal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eravikulam NP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Munnar	3.53	4.31	2.35	10.20	7.06	4.71	0.00
Mankulam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idukki WLD	0.49	0.49	0.00	0.98	0.00	0.49	0.00
Thekkadi WLD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kothamangalam	3.55	6.77	7.74	18.06	2.58	5.48	0.00
Kottayam	1.33	1.33	0.00	2.67	0.00	0.00	0.00
Highrange Circle	**1.77**	**2.69**	**2.31**	**6.77**	**2.00**	**2.31**	**0.00**
Ranni	0.00	4.38	5.00	9.38	0.00	1.88	0.00
Konni	3.81	13.33	8.57	25.71	0.00	0.00	0.00
Achancovil	0.00	0.00	0.61	0.61	1.21	2.42	0.00
Punalur	2.00	10.00	0.00	12.00	0.00	2.00	0.00
Thenmala	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trivandrum	0.00	0.83	0.00	0.83	0.00	3.33	0.00
Trivandrum WLD	0.45	2.27	3.64	6.36	4.09	3.18	0.00
Southern Circle	**0.72**	**3.81**	**2.68**	**7.22**	**1.13**	**2.06**	**0.00**