

# Structure of plant community in tropical deciduous forests of Kanyakumari Wildlife Sanctuary, India

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**Abstract.** Kothandaraman S, Sundarapandian S. 2017. Structure of plant community in tropical deciduous forests of Kanyakumari Wildlife Sanctuary, India. *Biodiversitas* 18: 391-400. Plant community structure of two tropical deciduous forest sites (I and II which are in different locations with different terrain characteristics viz., elevation and slope pattern) in Kanyakumari Wildlife Sanctuary, Western Ghats were assessed using standard phytosociological methods. Ten plots of 20 m x 20 m each were laid for woody species enumeration and 40 quadrats of 1 m x 1 m (4 in each plot) for understorey vegetation (herbs and plant species that are < 1 m in height) in each site. Overall, 76 plant species were recorded from 41 families, of which 23 contribute to understory. Site I (62) was twice as speciose as site II (31). Greater diversity index of adult woody vegetation was observed in site I (2.30) than site II (2.01). The woody individuals (diameter at breast height, DBH  $\geq$  10 cm) were more abundant in site I (518 individuals ha<sup>-1</sup>) than site II (448 individuals ha<sup>-1</sup>). The basal area of adult trees in sites I and II are 34.7 m<sup>2</sup> ha<sup>-1</sup> and 30.8 m<sup>2</sup> ha<sup>-1</sup> respectively. Euphorbiaceae was the most speciose family in both the sites. Twenty-five families in site I and seventeen families in site II were represented by singletons. Diameter class-wise distribution of adult trees showed a typical 'reverse J-shaped' curve indicating good regeneration status. Concerning understory, site I (19 species) has a greater diversity than site II (six species). The observed differences in the vegetation patterns between the two deciduous forest sites are possibly due to variations in elevation, terrain features and edaphic characteristics.

**Keywords:** Phytodiversity, species richness, tropical forests, Western Ghats

## INTRODUCTION

India has a vast expanse of forest cover (329 mha) and houses a total of 47,513 plant species (Singh and Dash 2014), that represents 11.4% of the world flora (Arisdason and Lakshminarasimhan 2016). Studying forest stand structure is very important to understand forest ecosystems (Ozcelik 2009; Naidu and Kumar 2016). Plant community structure, species composition and ecosystem functions are the most important ecological characteristics of forest ecosystems that correspondingly respond to environmental and anthropogenic changes (Sundarapandian and Karoor 2013). Krishnamurthy et al. (2010) and Thinh et al. (2015) reflect that floristic composition depicts the health of forests.

Tropical ecosystems are usually perceived to be rich biodiversity reserves (Apguaua et al. 2015; Gandiwa et al. 2016). About 54% and 37% of Indian tropical forests are classed as dry and moist deciduous forests respectively (Kaul and Sharma 1971; Krishnamurthy et al. 2010). As tropical trees are highly species-diverse, inventorying tropical forests are quite interesting (Condit et al. 1996, Pragasan and Parthasarathy 2009). Tree diversity differs from place to place in tropical forests due to dissimilarities in biogeography, habitat suitability, responses to climate change and anthropogenic pressures (Whitmore 1993; Sundarapandian and Karoor 2013).

Worldwide, 90% of the tropical forests lie outside protected areas (WWF 2002). Tropical forests are highly

threatened by anthropogenic activities, even within protected areas (Curran et al. 2004; Sahu et al. 2010; Majumdar and Datta 2015). In India, the annual rate of forest loss is reported to be about 3.5% (Puyravaud et al. 2010). Large patches of tropical forests are being deforested every year leading to rapid loss of biodiversity (Panda et al. 2013) and accelerated species loss would eventually result in the collapse of some ecosystems (Kharkwal et al. 2005; Mutiso et al. 2015). Reddy et al. (2008) have observed that tropical deciduous forests are the most threatened ecosystems in India, due to economic exploitation.

Deciduousness is an adaptive phenomenon in tropical forests that is due to the synergistic effect of drought, soil moisture and tree characteristics (Singh and Kushwaha 2016). Tropical deciduous forests are characterized by mosaics of tree functional types that exhibit pronounced variation in terms of the duration of deciduousness and time of bud break of vegetative buds (Borchert et al. 2002; Singh and Kushwaha 2016). The vegetation structure and species composition of these forests differ with the duration of the wet season, the amount of rainfall, latitude, altitude and anthropogenic activities (Reddy et al. 2008).

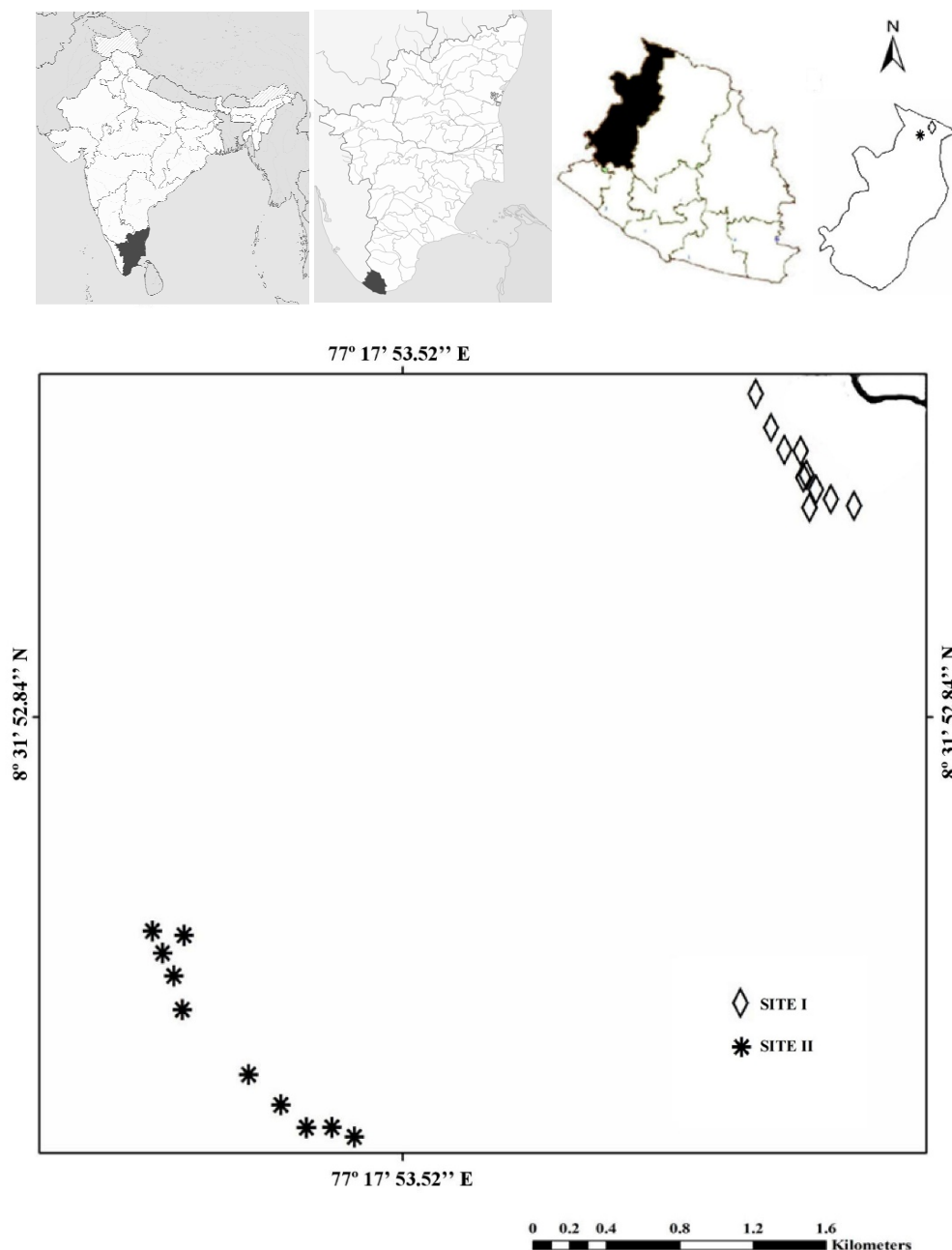
The Western Ghats, a biodiversity hotspot is endowed with characteristic complex patterns of vegetation structure and variation in species distribution (Pascal 1988; Giriraj et al. 2008). The southern Western Ghats has been reported to be the richest in terms of species composition and concentration of endemic taxa (Nayar 1996; Sarvalingam

and Rajendran 2016). Forests in the Western Ghats, although protected by Forest Conservation Act of 1980, are being subjected to natural calamities and human activities that lead to biodiversity loss, opening of canopies, invasion, etc. ultimately resulting in changes in forest structure and species composition (Bhat et al. 2011; Murthy et al. 2016). Studies on the forest structure of deciduous forests in Kanyakumari Wildlife Sanctuary are limited (Sundarapandian and Swamy 1997, 2000). The present study has been undertaken with the aim of studying the community structure of two tropical deciduous forest sites in two different elevations of Kanyakumari Wildlife Sanctuary that forms the tail-end of Western Ghats.

## MATERIALS AND METHODS

### Study area

Kanyakumari Wildlife Sanctuary, Western Ghats, India is located between  $77^{\circ}10'$ - $77^{\circ}35'$  E and  $8^{\circ}5'$ - $8^{\circ}35'$  N. They form the southern part of Agastyamalai region and are flanked by Neyyar Wildlife Sanctuary of Kerala in the west and Kalakkad-Mundanthurai Tiger Reserve of Tamil Nadu in the east. The area gets an average annual rainfall of 137 cm and the average monthly maximum and minimum temperatures are 30 and  $24^{\circ}\text{C}$ . Forests of Kanyakumari Wildlife Sanctuary are rich in biodiversity with several microhabitats, due to its exposure to wide



**Figure 1.** Map showing study area and two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

range of climatic conditions and its geographic location at the southernmost tip of the subcontinent. There are 14 forest types in this sanctuary, based on Champion and Seth's classification (1968). The rainfall varies from 50 to 310 cm and elevation up to 1829 m asl across the different forest types (Tamil Nadu Forest Department 2016., [http://forests.tn.nic.in/WildBiodiversity/ws\\_kws.html](http://forests.tn.nic.in/WildBiodiversity/ws_kws.html)).

## Methods

Two tropical deciduous forest sites (I and II) were selected that differ in their location as well as terrain characteristics (Figure 1). Site I is sloped while site II is flat. Site I is located at a higher elevation (530-630 m asl) than site II (317-360 m asl). Both the sites are left unperturbed in the last few years, although site I is more undisturbed as it is located far away from human settlements and it has restricted entry. Soil bulk density and total nitrogen content were significantly more in site II than site I. To study and compare the community structure of these two sites, twenty plots of 20 m x 20 m each were laid randomly, ten in each site. The enumerated individuals were classified into three categories: saplings (those with diameter at breast height, i.e., DBH < 3 cm), juveniles (those with DBH 3-10 cm) and adults ( $\geq 10$  cm DBH). To quantify understory, a total of forty quadrats (4 in each plot) of 1 m x 1 m were laid in each site. Density, basal area, frequency, importance value index (IVI), family index and diameter class-wise distribution were calculated for each site and compared. Diversity indices were computed using Past 3.1 program (version 3.1; Øyvind Hammer, Natural History Museum, University of Oslo).

## RESULTS AND DISCUSSION

### Results

#### *Species richness and diversity*

Species richness and diversity varied distinctly in different sets of populations (viz., saplings, juveniles, adults and understory) in both the sites (Table 1). Overall, 76 species were recorded from 41 families, of which 28 contribute to woody vegetation and 23 to understory. Site I (62) was twice as speciose as site II (31). Seventeen woody species were common to both the sites. Site I had high species richness in the case of both woody as well as understory vegetation. The understory of site II was monodominant with *Themeda cymbaria*. Greater diversity index of adult woody vegetation was observed in site I (2.30) than site II (2.01) while dominance index showed a reverse trend. However, site I had a lesser evenness index than site II in the case of juveniles and adults of woody vegetation as well as understory. Fisher's alpha was also greater in site I than site II.

#### *Family dominance*

Euphorbiaceae was the most speciose family in site I (nine species), while in site II, both Euphorbiaceae and Combretaceae share the dominance (five species each; Table 2). Twenty-five families in site I and seventeen families in site II were represented by singletons. However,

in terms of abundance, Fabaceae, Poaceae and Zingiberaceae in site I and Poaceae, Rhamnaceae and Melastomataceae in site II were dominant.

#### *Density, stand basal area and IVI*

There was a great variation in density, basal area and IVI values between the two sites (Table 3) and on the whole, 1799 tree individuals were counted. The woody ( $\geq 10$  cm DBH) individuals were more abundant in site I (518 individuals  $\text{ha}^{-1}$ ) than site II (448 individuals  $\text{ha}^{-1}$ ). With regards to understory, site II (401000 individuals  $\text{ha}^{-1}$ ) is greater than site I (280230 individuals  $\text{ha}^{-1}$ ), due to monodominance by *T. cymbaria*, a grass. The basal area of adult trees in sites I and II are 34.7  $\text{m}^2 \text{ha}^{-1}$  and 30.8  $\text{m}^2 \text{ha}^{-1}$  respectively. The basal area was higher in site I (7.52  $\text{m}^2 \text{ha}^{-1}$ ) than site II (4.20  $\text{m}^2 \text{ha}^{-1}$ ) for understory vegetation too. As for IVI, *Pterocarpus marsupium*, *Ficus beddomei* and *Terminalia paniculata* in site I and *T. paniculata*, *Terminalia elliptica* and *Dillenia pentagyna* in site II were the dominants in adult population.

#### *Population structure*

The population structure of saplings and juveniles are presented in Table 4. *Aporosa cardiosperma*, *Chionanthus ramiflorus* and *Croton malabaricus* in site I and *A. cardiosperma*, *Helicteres isora* and *T. paniculata* in site II contributed to the highest numbers among the sapling population. Similarly, among juveniles, *A. cardiosperma*, *C. malabaricus* and *C. ramiflorus* in site I and *T. paniculata*, *A. cardiosperma* and *H. isora* in site II were represented by most number of individuals. *P. marsupium*, *F. beddomei* cum *T. paniculata* and *T. paniculata*, *D. pentagyna* cum *T. elliptica* dominated the adult population in sites I and II respectively. Seven species in site I and six species in site II were represented by only a single individual. Overall, fifteen species in site I and eight species in site II were represented in all the three stages of population viz., saplings, juveniles and adults. Twelve species in site I and six species in site II were represented as only saplings and juveniles. Four species in site I are represented as juveniles and adults. *Aporosa indo-acuminata* is the only species that occurs in both sapling and adult stages in site II. Four species in site I and eight species in site II occur as only saplings. Five species in site I occur as only juveniles. Four species in site I (*Ficus benghalensis*, *Gossypium hirsutum*, *Grewia tiliifolia* and *Melia dubia*) and two species in site II (*Briedelia retusa* and *Terminalia bellirica*) were present only in adult form.

#### *Size class distribution*

Diameter class-wise distribution of adult trees in both the sites showed a typical 'reverse J-shaped' curve. Both the density and species richness decreased with increase in diameter class (Figure 2). Low diameter class individuals (viz., 10-20 cm DBH) displayed the highest level of species richness – 90.9% in site I and 91.7% in site II. Around 73.4% and 68.6% of individuals belong to low diameter class (10-30 cm DBH), of which 45.4 and 38.5% come under 10-20 cm size class. Only about 5-8% of the individuals belonged to the high diameter classes ( $\geq 50.1$

**Table 1.** Consolidated details of phytosociological analyses of two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

Parameter	Site I	Site II
<b>No. of species (No. 4000 m<sup>-2</sup>)</b>		
Tree saplings	31	23
Tree juveniles	36	14
Tree adults	22	12
Understory	19	6
Total no. of species	62	31
<b>Density (No. ha<sup>-1</sup>)</b>		
Tree saplings	1420	948
Tree juveniles	910	253
Tree adults	518	448
Understory	280230	401000
<b>Basal area (m<sup>2</sup>ha<sup>-1</sup>)</b>		
Tree saplings	0.41	0.19
Tree juveniles	2.35	0.79
Tree adults	34.76	30.83
Understory	7.52	4.20
<b>Species diversity index</b>		
Tree saplings	2.59	2.21
Tree juveniles	2.66	2.15
Tree adults	2.30	2.01
Understory	1.49	0.10
<b>Dominance index</b>		
Tree saplings	0.13	0.19
Tree juveniles	0.13	0.16
Tree adults	0.15	0.16
Understory	0.32	0.97
<b>Evenness index</b>		
Tree saplings	0.43	0.40
Tree juveniles	0.40	0.61
Tree adults	0.45	0.62
Understory	0.23	0.18
<b>Fisher's alpha</b>		
Tree saplings	7.04	5.39
Tree juveniles	9.92	4.41
Tree adults	6.23	2.90
Understory	1.71	0.47

**Table 2.** Family-wise contribution of genera (G), species (S) and abundance (A; No. 4000 m<sup>-2</sup>) in two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

Family	Site I			Site II		
	G	S	A	G	S	A
Acanthaceae	1	1	2600	0	0	0
Anacardiaceae	1	1	9	2	2	27
Annonaceae	0	0	0	1	1	9
Apocynaceae	1	1	35	1	1	300
Araceae	1	1	1900	0	0	0
Arecaceae	1	1	600	0	0	0
Aristolochiaceae	1	1	400	0	0	0
Bignoniaceae	1	1	1	0	0	0
Celastraceae	1	1	52	0	0	0
Clusiaceae	1	1	12	0	0	0
Combretaceae	1	3	62	2	5	261
Dilleniaceae	0	0	0	1	1	50
Dipterocarpaceae	1	1	62	0	0	0
Ebenaceae	1	3	67	0	0	0
Elaeocarpaceae	1	1	6	0	0	0
Euphorbiaceae	7	9	444	4	5	227
Fabaceae	4	4	47075	1	1	15
Icacinaeae	2	2	28	1	1	10
Lauraceae	1	1	4	0	0	0
Lecythidaceae	1	1	19	1	1	47
Liliaceae	1	1	2400	0	0	0
Lythraceae	0	0	0	1	1	12
Malvaceae	0	0	0	1	1	11
Melastomataceae	0	0	0	1	1	700
Meliaceae	2	2	3	1	1	1
Moraceae	1	3	72	1	1	2
Myrsinaceae	1	1	13	1	1	6
Myrtaceae	1	1	1	0	0	0
Oleaceae	2	2	101	0	0	0
Piperaceae	1	1	2100	0	0	0
Poaceae	1	1	40400	1	1	158000
Rhamnaceae	1	1	1	1	1	1100
Rubiaceae	4	4	2886	1	1	17
Sapindaceae	2	2	8	0	0	0
Sapotaceae	1	1	8	0	0	0
Selaginellaceae	1	1	800	0	0	0
Sterculiaceae	1	1	1	2	2	63
Tiliaceae	1	1	1	0	0	0
Verbenaceae	1	1	58	1	1	1
Viscaceae	1	1	2	1	1	200
Zingiberaceae	3	3	11000	0	0	0

cm DBH). The diameter class distribution of dominant species in sites I and II are presented in Figure 3. Interestingly, it has been observed that although the curve depicting the diameter class-wise distribution of all adult trees is reverse J-shaped, only a few dominant species viz., *A. cardiosperma* and *C. malabaricus* in site I and *T. paniculata* in site II exhibited this trend.

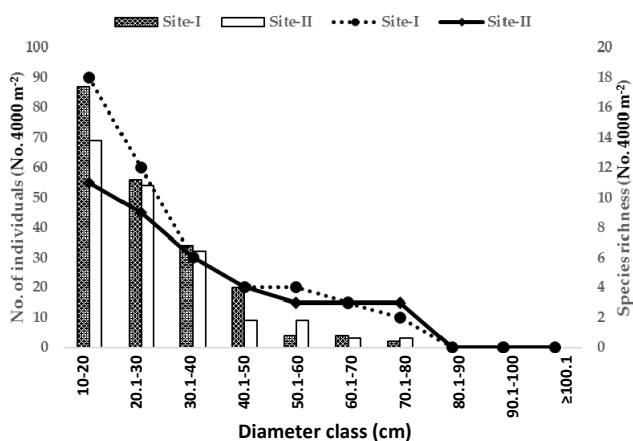
## Discussion

The two deciduous forest sites in the Western Ghats of Kanyakumari Wildlife Sanctuary showed a remarkable variation in their vegetation structure and species composition. In the present study, a total of 76 plant species were recorded, of which 28 contribute to woody

vegetation. The species diversity reported in the present study is comparable with the study of Varghese and Balasubramanian (1999) from a wet evergreen forest of Agastyamalai region in Kerala, Myo et al. (2016) from a mixed deciduous and deciduous dipterocarp forests in Madan watershed, Myanmar and Surpam et al. (2016) from woodland of Seminary Hills in Nagpur. However, the values obtained here were lower than the studies reported by Giriraj et al. (2008) from wet evergreen forests of Kalakkad-Mundanthurai Tiger Reserve, Sahoo and Davidar (2013) from dry deciduous forests dominated by sal in Similipal Tiger Reserve in Odisha, Gandhi and Sundarapandian (2014) from dry deciduous forests of Tiruvannamalai in Tamil Nadu, Mutiso et al. (2015) from

**Table 3.** Abundance, basal area and IVI of adult woody species in two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

Species	Abundance (No. 4000 m <sup>-2</sup> )		Basal Area (m <sup>2</sup> 4000 m <sup>-2</sup> )		IVI	
	Site I	Site II	Site I	Site II	Site I	Site II
<i>Aporosa cardiosperma</i> (Gaertn.) Merr.	17	0	0.33	0	21.69	0
<i>Aporosa indo-acuminata</i> Chakrab. & N.P. Balakr.	0	1	0	0.02	0	2.33
<i>Briedelia retusa</i> (L.) A. Juss.	2	1	0.06	0.01	2.77	2.28
<i>Buchanania lanzan</i> Spreng.	0	15	0	0.55	0	24.11
<i>Calophyllum inophyllum</i> L.	8	0	0.32	0	13.12	0
<i>Careya arborea</i> Roxb.	4	17	0.23	0.77	6.35	25.43
<i>Cassine glauca</i> (Rottb.) Kuntze	1	0	0.07	0	2.37	0
<i>Chionanthus ramiflorus</i> Roxb.	1	0	0.01	0	1.94	0
<i>Croton malabaricus</i> Bedd.	2	0	0.03	0	3.97	0
<i>Dillenia pentagyna</i> Roxb.	0	32	0	1.36	0	45.02
<i>Ficus beddomei</i> King	43	0	3.77	0	60.37	0
<i>Ficus benghalensis</i> L.	4	0	0.22	0	7.67	0
<i>Ficus hispida</i> L. f.	2	0	0.10	0	4.45	0
<i>Grewia tiliifolia</i> Vahl L.	1	0	0.01	0	1.95	0
<i>Hopea parviflora</i> Bedd.	17	0	0.69	0	18.71	0
<i>Isonandra perrottetiana</i> A. DC	3	0	0.45	0	6.09	0
<i>Lepisanthes tetraphylla</i> (Vahl) Radlk.	1	0	0.04	0	2.14	0
<i>Melia dubia</i> Cav.	1	0	0.01	0	1.97	0
<i>Monoon fragrans</i> (Dalz.) B. Xue & R. M. K. Saunders	0	1	0	0.04	0	2.46
<i>Phyllanthus emblica</i> L.	9	15	0.43	0.40	13.00	21.27
<i>Pterocarpus marsupium</i> Roxb.	57	10	5.29	1.67	79.46	25.61
<i>Tabernaemontana gamblei</i> Subram. & Henry	1	0	0.08	0	2.41	0
<i>Tamarindus indica</i> L.	2	0	0.03	0	3.97	0
<i>Terminalia bellirica</i> (Gaertn.) Roxb.	0	1	0	0.01	0	2.29
<i>Terminalia chebula</i> Retz.	2	8	0.03	0.33	3.95	15.22
<i>Terminalia elliptica</i> Willd.	0	29	0	3.47	0	60.45
<i>Terminalia paniculata</i> Roth	22	49	1.56	3.70	34.34	73.54
<i>Vitex altissima</i> L.f.	7	0	0.16	0	7.31	0

**Figure 2.** Diameter class-wise distribution of adult trees in two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

Mau forests in Kenya and Gandiwa et al. (2016) from semi-arid Mapungubwe Cultural Landscape in South Africa, while these were higher than the reports of Karthikeyan and Dharmotharan (2015) from a tropical dry deciduous forest in a sacred grove of Dharmapuri in Tamil

Nadu, Pradhan and Rahaman (2015) from three tropical dry deciduous forests in West Bengal and Carrión-Paladines and García-Ruiz (2016) from a dry deciduous forest in southern Ecuador. Variation in composition of tree species and the proportion of dominant species could be directly related to elevation and rainfall distribution (Reddy et al. 2008; Mohandass et al. 2016). In this study, site I is located in an elevation (530-630 m asl) that is higher than that of site II (317-360 m asl), which could be one of the causes for variation in species diversity. Although both the sites have been left undisturbed in the last few years, site I has more restricted access than site II and is located far away from human settlements. Based on enquiry with the localites, it was known that site II was subjected to recurrence of annual surface fires before declaration as a wildlife sanctuary (2008).

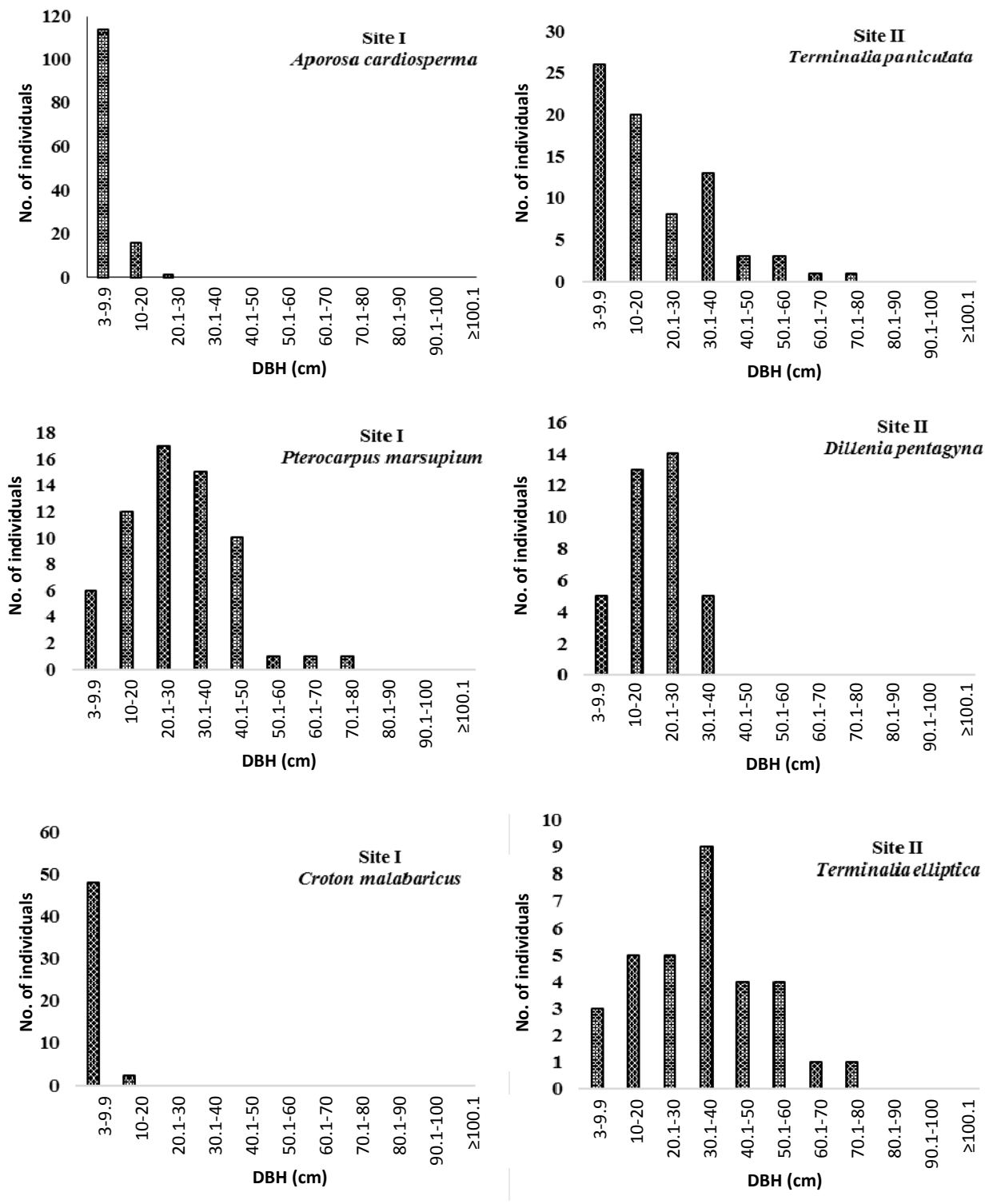
The species diversity index values for adult woody vegetation noted in the present study are 2.30 (site I) and 2.01 (site II). These indices are well within the range as reported by Joglekar et al. (2015); close to the reports of Swamy et al. (2000), Sundarapandian and Karoor (2013); but lower than the values observed by Reddy et al. (2008), Mohandass et al. (2016) and Murthy et al. (2016). As regards to understory, site II had a greater dominance index than site I due to the monodominance of *T. cymbaria*, which also reasons for its lesser evenness index.

**Table 4.** Population structure of saplings and juveniles in two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

Species	Saplings (No. 4000 m <sup>-2</sup> )		Juveniles (No. 4000 m <sup>-2</sup> )	
	Site I	Site II	Site I	Site II
<i>Agrostisachys borneensis</i> Becc.	10	0	3	0
<i>Antidesma ghaesembilla</i> Gaertn.	0	1	0	0
<i>Aporosa cardiosperma</i> (Gaertn.) Merr.	160	146	114	25
<i>Aporosa indo-acuminata</i> Chakrab. & N.P. Balakr.	0	27	0	0
<i>Ardisia solanacea</i> Roxb.	0	6	0	0
<i>Briedelia retusa</i> (L.) A. Juss.	0	0	2	0
<i>Buchanania lanzan</i> Spreng.	2	1	7	6
<i>Calophyllum inophyllum</i> L.	2	0	2	0
<i>Careya arborea</i> Roxb.	8	24	7	6
<i>Cassine glauca</i> (Rottb.) Kuntze	39	0	12	0
<i>Chionanthus ramiflorus</i> Roxb.	73	0	23	0
<i>Cinnamomum malabathrum</i> Miq.	4	0	0	0
<i>Cipadessa baccifera</i> (Roth) Miq.	0	1	2	0
<i>Croton malabaricus</i> Bedd.	59	0	48	0
<i>Dalbergia latifolia</i> Roxb.	2	0	4	0
<i>Dillenia pentagyna</i> Roxb.	0	13	0	5
<i>Dimocarpus longan</i> Lour.	5	0	0	0
<i>Diospyros affinis</i> Thw.	20	0	18	0
<i>Diospyros melanoxyton</i> Roxb.	26	0	1	0
<i>Diospyros paniculata</i> Dalz.	1	0	1	0
<i>Elaeocarpus variabilis</i> Zmarzty	3	0	3	0
<i>Ficus beddomei</i> King	9	2	5	0
<i>Ficus hispida</i> L. f.	3	0	6	0
<i>Gossypium hirsutum</i> L.	0	9	0	2
<i>Helicteres isora</i> L.	1	52	0	10
<i>Hopea parviflora</i> Bedd.	28	0	17	0
<i>Isonandra perrottetiana</i> A. DC	1	0	4	0
<i>Lagerstroemia microcarpa</i> Wight	0	12	0	0
<i>Lepisanthes tetraphylla</i> (Vahl) Radlk.	0	0	2	0
<i>Maesa indica</i> (Roxb.) DC	6	0	7	0
<i>Mallotus aureo-punctatus</i> (Dalz.) Müll.Arg.	5	0	1	0
<i>Mallotus ferrugineus</i> (Roxb.) Müll.Arg.	2	0	0	0
<i>Mangifera indica</i> L.	0	5	0	0
<i>Monoon fragrans</i> (Dalz.) B. Xue & R. M. K. Saunders	0	5	0	3
<i>Nothapodytes nimmoniana</i> (Graham) Mabb.	3	9	3	1
<i>Olea dioica</i> Roxb.	3	0	1	0
<i>Pavetta indica</i> L.	0	16	5	1
<i>Phyllanthus emblica</i> L.	0	2	2	9
<i>Pterocarpus marsupium</i> Roxb.	3	2	6	3
<i>Stemonurus tetrandrus</i> (Wall. ex Roxb.) Alston	17	0	5	0
<i>Sterculia villosa</i> Roxb.	0	1	0	0
<i>Stereospermum chelonoides</i> (L.f.) DC.	0	0	1	0
<i>Syzygium cumini</i> (L.) Skeels	0	0	1	0
<i>Tabernaemontana gamblei</i> Subram. & Henry	23	0	11	0
<i>Tamarindus indica</i> L.	0	0	1	0
<i>Terminalia bellirica</i> (Gaertn.) Roxb.	0	0	1	0
<i>Terminalia chebula</i> Retz.	4	5	1	1
<i>Terminalia elliptica</i> Willd.	0	5	0	3
<i>Terminalia paniculata</i> Roth	16	34	16	26
<i>Vitex altissima</i> L.f.	30	1	21	0

Tropical forests usually possess several tree species. However, forests that are dominated by one or only a few species are also prevalent on all tropical continents in different environments (Richards 1996; Peh et al. 2011). Site I had a higher stand density than site II in the case of

adult woody vegetation (site I - 518 individuals ha<sup>-1</sup>, site II - 448 individuals ha<sup>-1</sup>), but site II was greater than site I (site I - 280230 individuals ha<sup>-1</sup>, site II - 401000 individuals ha<sup>-1</sup>) in the case of understory. The latter is so, because *T. cymbaria*, a grass species dominated the understory of site



**Figure 3.** Diameter class-wise distribution of dominant species in two tropical deciduous forest sites in Kanyakumari Wildlife Sanctuary, Western Ghats, India

II. With regards to basal area, which is often perceived as an indicator of growing stock and biomass production (Murthy et al. 2016), site I had greater values than site II in both woody vegetation as well as understory, although site II had a higher density than site I in the understory. This is

so because, site I is comprised of diverse understory with sprouts of woody species’ saplings and juveniles as well, while site II is just monodominant with the grass *T. cymbaria*, with a very rare occurrence of other species. Concerning woody vegetation, trees in site I are closely

distributed, while those in site II are sparsely distributed. The values of the basal area of adult woody vegetation recorded in the present study are higher than the values obtained for low elevation forest, but lower than the values of mid-elevation forest and high elevation forest, in pertinence to the study conducted in the tropical forests of Kanyakumari by Swamy et al. (2000). The values of the basal area are also higher than those observed by Gandhi and Sundarapandian (2014) and Gupta and Kumar (2014). The values were comparable with other reports (Sundarapandian and Karoor 2013; Murthy et al. 2016), but lower than the values recorded by Davidar et al. (2007), Bharathi and Prasad (2015) and Mohandass et al. (2016). *P. marsupium* and *F. beddomei* in site I, *T. paniculata* and *T. elliptica* in site II were the highest contributors to basal area.

The composition, distribution and density of saplings and juveniles depict the future structure of the forest (Myo et al. 2016). Khan et al. (1986) stated that the response of the tree saplings or sprouts to the prevailing microenvironment largely determines the density of trees in a forest. A population structure comprising of an ample number of saplings, juveniles and young trees indicates satisfactory regeneration behavior, while an insufficient number of saplings and juveniles denotes poor regeneration (Saxena and Singh 1985; Bharathi and Prasad 2015). An abundant population of saplings and juveniles as observed in the present study highlights the regeneration status of different species (Swamy et al. 2000) in these sites. *A. cardiosperma* contributed largely to both sapling and juvenile populations of sites I and II. The other notable contributors are *C. ramiflorus* and *C. malabaricus* in site I and *T. paniculata* and *H. isora* in site II. In the case of adults, *P. marsupium* and *F. beddomei* in site I and *T. paniculata* and *D. pentagyna* were the most predominant species. Some species are represented in all three stages of development, but many others are characterized by only one or two stages. This kind of species-level variation in population structure could be due to the differential preference of species in site quality, microclimate, levels of seed predation, pathogenic attack on seeds, topography and forest stature (Sundarapandian and Karoor 2013). According to Khumbongmayum et al. (2005), differences in the light intensity, nutrient supply, understory community and microenvironmental conditions in the gaps greatly influence the differential growth behavior of saplings of different tree species.

Euphorbiaceae and Combretaceae have been observed to be top-most contributors to species diversity. Nevertheless, in the case of abundance, Fabaceae and Poaceae are the predominant families. Similar results listing the abovesaid families as dominant families were reported by Swamy et al. (2000), Panda et al. (2013), Sundarapandian and Karoor (2013) and Naidu and Kumar (2016).

Very often the health of a forest is judged by plotting the size class distribution of individuals (Bhat et al. 2011) as it indicates the regenerative capacity of the forest (Murthy et al. 2016). Regeneration is a vital process for the existence of species in the community (Khumbongmayum

et al. 2005). The presence of more small-sized trees than large-sized ones is perceived as an indicator of a regenerating forest (Bhat et al. 2011). The present study showed a decline in species richness and density with increasing diameter class, indicating a characteristic 'reverse J-shaped' curve, which in turn indicates a good regeneration status. Similar results were obtained by Ganesh et al. (1996), Varghese and Balasubramanian (1999), Bhat et al. (2011), Joglekar et al. (2015) and Mohandass et al. (2016). Swamy et al. (2010) stated that many tropical forests have a great intrinsic potential of self-maintenance though, in recent years, many of them are losing this ability due to lots of biotic interferences like anthropogenic activities. Chauhan et al. (2010) opined that species composition in a forest depends on the regeneration of species composing the forest in space and time.

As stated by Muhammad et al. (2016), site ecological factors greatly influence diversity, density and distribution. Tropical forest structure and composition are noted to be influenced by elevation (Vazquez and Givnish 1998; Wiafe 2014), topography (Mendez-Toribio et al. 2016; Zhang et al. 2016) as well as soil characteristics (Katabuchi et al. 2012; Toledo et al. 2012). Therefore, the observed differences in the vegetation patterns in the two deciduous forest sites may be possibly due to variations in elevation, terrain and edaphic characteristics. According to Reddy et al. (2008), moist deciduous forest epitomizes a transitional stage from dry deciduous to semi-evergreen vegetation and Thomas and Baltzer (2002) also stated that the transformed semi-evergreen forests usually have clumping of both deciduous and evergreen species. In the present study, site I has comparatively many saplings and juveniles of evergreen species than deciduous species, which is a good sign indicating a transition from deciduous forest to semi-evergreen forest as stated by Thomas and Baltzer (2002). However, regeneration of tree species in a sapling stage is generally low in site II, which could be due to occasional surface fires. Sundarapandian and Swamy (2000) observed that the recurrence of annual fires affects the regeneration directly through burning of seeds, seedlings and saplings and indirectly alters the edaphic characteristics. Moreover, the understory in site II is dominated by a single grass species (*Themeda cymbaria*), which suppresses the growth of saplings. Keel and Prance (1979) stated that the dominance increases as a function of stress, while Jacobs (1987) explained that in tropical forests, dominance by single species often indicates past damage. Since understory vegetation in site II is dominated by a single species, it could be inferred that this site may be subjected to anthropogenic pressures in the recent past. From the observed results, it could be concluded that both the deciduous forest sites display unique vegetation patterns, signifying that while one is transitional, the other is apparently unchanging.

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