

Species composition and diversity of Teak plantation in Karnaphuli range, Kaptai, Rangamati, Bangladesh

Видов состав и диверзитет во плантажа со тиково дрво во Карнафули, Каптаи, Рангамати, Бангладеш

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Abstract



Teak (*Tectona grandis* L.f.) is a widely planted hardwood tree in Bangladesh, without considering its effects on native forest plants. To study the plant species composition and diversity in a Teak plantation a quantitative vegetation inventory was performed using transect method in the Karnaphuli range of Kaptai reserve forest, Rangamati district, Bangladesh during 2015-2017. The size of the quadrates was 20×20m, 5×5m and 1×1m for trees, shrubs and herbs respectively, to get density, abundance, relative density, relative frequency, basal area, etc. The species composition is presented by density and frequency; the dominance of species is presented by Importance Value Index; the species diversity and concentration of dominance is presented by Shannon's index of diversity. A total of 78 plant species, including 34 trees, 19 shrubs and 25 herbs belonging to 40 families and 70 genera were noticed during the study. The *Tectona grandis* among trees, *Lantana camara* in shrubs and *Heliotropium indicum* in herbs were found to be the dominant species. The family Euphorbiaceae among trees, Rubiaceae and Verbenaceae among shrubs and Araceae among herbs were observed to be the dominant families. Tree species showed contagious whereas shrubs and herb species showed random to contagious distribution pattern. The Shannon's diversity index for trees, shrubs and herbs were 1.486, 2.624 and 2.944, respectively. This study provides in-depth information about the plant species phytosociological parameters and diversity indices of Teak plantation, which is essential to make conservation strategies for the protection and development of plant biodiversity.

Key Words: *Tectona grandis*, Teak, Diversity, Species composition, Karnaphuli range and Kaptai

Апстракт

Тиковото дрво (*Tectona grandis* L.f.) е широко распространето садено дрво во Бангладеш без да се води сметка за неговото влијание врз автохтоните растенија. Квантитативни вегетационски истражувања со помош на метод со трансекти беа спроведени во тикова плантажа во подрачјето Карнафули во Шумскиот резерват Каптаи (регион Рангамати, Бангладеш) во тек на

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2015-2017 година со цел да се утврди нејзиниот флористички состав и диверзитет. Големината на експерименталните површини беше 20×20m за дрвјата, 5×5m за грмушките и 1×1m за тревестите растенија. Во нив беа анализирани густината, абундантноста, релативната густина, релативната фреквенција, базалната површина, итн. Видовиот состав е претставен преку густината и фреквенцијата; доминантноста на видовите е прикажана преку Индексот за значајноста (IVI- Importance Value Index); диверзитетот на видови и доминантноста се прикажани преку Шеноновиот индекс на диверзитет (Shannon's index of diversity).

Беа регистрирани вкупно 78 дрвенести, 19 грмушести и 25 тревести видови кои припаѓаат на 40 фамилии и 70 родови. Тиковото дрво помеѓу дрвенестите видови, *Lantana camera* од грмушките и *Heliotropium indicum* од тревестите растенија беа доминантни видови. Фамилијата Euphorbiaceae беше доминантна кај дрвенестите, Rubiaceae и Verbenaceae кај грмушестите и Agaceae кај тревестите растенија.

Дрвенестите видови покажаа групов распоред, додека грмушестите и тревестите растенија имаа случаен до групов распоред. Шеноновиот индекс за диверзитет за дрвенестите, грмушестите и тревестите видови изнесуваше 1,486, 2,624 и 2,944 соодветно. Резултатите од оваа студија прикажуваат детална информација за фитосоциолошките параметри и индексите за диверзитет во тиковата плантажа што е основа за конзервациските стратегии, како и за заштита и унапредување на растителниот диверзитет.

Клучни зборови: *Tectona grandis*, тиково дрво, диверзитет, видов состав, Карнафули, Каптаи

Introduction

Teak (*Tectona grandis* L.f., Family: Verbenaceae) is a widely planted tropical hardwood that has significant economic potential (FAO 2001; Niskanen 1988). It is considered as a grand jewel in the diadem of tree species that occur naturally in the tropical forests of the world (Sankaran 2003). Because of its versatile range of uses, Teak is preferred all over the world and it is dominant component of diverse forest types in the Indian Subcontinent (Katwal 2005). Although the natural occurrence of Teak is limited to India, Laos, Myanmar and Thailand, it is grown in an around 60 countries in Asia, Africa and Latin America (Jayaraman 2011) while it was grown only in 36 countries in 2003 (Chandrasekharan 2003). Because of its high wood quality (Jayaraman 1998; Pérez 2005; FAO 2009) and fire-resistance (Ladrach 2009), Teak is the world's most cultivated high-grade tropical hardwood, covering approximately 6 million hectares worldwide (Bhat & Hwan Ok Ma 2004 In: Pérez 2005). In terms of properties and appearance, Teak is the most demanding premier hardwood species. Teak was preferred for plantations since the initiation of plantation forestry in Bangladesh in 1871 (FAO 2010).

Considering the international value of Teak, the first effort establishment of Teak plantation in Bangladesh was in 1871 at the Sitapahar Range (now Kaptai Range) of

Chittagong Hill Tracts (CHTs) within an area of 4 ha (Hossain et al. 2008), without considering its effects on native plants/forest plants. After that it was extended to Chittagong, Cox's Bazar, and Sylhet districts in 1921 (Hossain et al. 2008) with an area variously reported as between 40000 and 216994 ha (Haque 2000; Muhammed et al. 2007). Now, Teak has dominated in the plantations for industrial wood in Chittagong, Chittagong Hill Tract (Khagrachari, Rangamati and Bandarban hill districts), Cox's Bazar and Sylhet with a coverage about 144000 ha (Hossain 2008). These plantations provide timber, poles, fuelwood and pulpwood and to some extent are also helping to conserve forest biodiversity and the environment (Hossain 1998). More than 70% of the total plantation area in CHTs were occupied by Teak (Rahman & Mustanoja 1978) but the more Teak monoculture has extended, the ecological uncertainties for the CHTs increase because hill slopes are uncovered and accelerating soil erosion (Feroz et al. 2014; Zaman et al. 2010).

Limited research has focused on the plant species composition along with the diversity in the Teak plantation, although they were established in Bangladesh 145 years ago. For sustainable plant diversity and forest management, it is important to know detailed plant species composition of Teak plantation. In order to achieve this goal, this study carried out with the following objectives: i. investigate

the understory plant species composition and their diversity and ii. investigate stand structure of tree species and their diversity in the Teak plantation of Karnaphuli range.

Materials and methods

The experiment was conducted in the Teak plantation area of Karnaphuli range in the Kaptai reserve forest, Rangamati district, Bangladesh during 2015-2016. The topography of the study area is diverse, from almost flat land to medium and high hillocks (Feroz et al. 2014; Rahman et al. 2013). About 10% of the area is occupied by well-drained flood plains (Rahman et al. 2013). The other area, owing to its steep slopes and bare surface, is often subject to soil erosion and landslides (Biswas et al. 2012). The parent materials are poor in weatherable minerals (Biswas et al. 2012). The soil texture is sandy to sandy loam (Biswas et al. 2012; Feroz et al. 2014). The soil pH ranges from 4.5 to 6.0 (BBS 2013). Mean annual rainfall is 2673 mm (BBS 2013) and mean annual temperature is 29.6°C (BBS 2013). The mean relative humidity is over 90% throughout the year (BBS 2013).

The transect method (Greig-Smith 1964), was used to study plant diversity of the area. Transects or straight lines were marked starting from the base of the study area at the end of the vegetation zone in the selected site. The lengths of transects were 500 m to 1 km in each of the selected habitats. Before the standardization of the plot size, species-area curve methods were used to assess the minimum required size of the plot. Based on that, 32 sampling plots (quadrates) were laid down with the size of each plot being 20×20 m for tree strata (Williams 1991), 5×5 m for shrubs and 1×1 m for herbs (Cottam & Curtis 1956; Saxena & Singh 1982; Nayak et al. 2000; Lu et al. 2004; Nautiyal 2008).

The total numbers of species in each plot were counted and then identified with the help of local experts and literature available (Das & Alam 2001; Prain 1903; Ahmed et al. 2008a). Major phytosociological attributes and diversity indices such as basal area, species density, relative density, frequency, relative frequency, relative dominance, and Importance Value Index, Simpson Index, Species Evenness Index, Shannon's Diversity Index (H) were calculated using standard methods stated in Tab. 1.

Table 1. Specifications of phytosociological parameters and diversity indices for the floral species available at Teak plantation, Karnaphuli range in Kaptai, Rangamati, Bangladesh

Biodiversity Attributes	Definitions	Sources
Basal Area (BA)	$BA = \frac{\pi}{4} e^2$	Chaturvedi and Khanna (1982).
Density (D)	$D = \frac{a}{b}$	Shukla and Chandel (2000)
Frequency (F)	$F = \frac{c}{b}$	Shukla and Chandel (2000)
Abundance (A)	$z = \frac{a}{c}$	Shukla and Chandel (2000)
Relative Density (RD)	$RD = \frac{n}{N} \times 100$	Dallmeier et al. (1992); Misra (1968)
Relative Frequency (RF)	$RF = \frac{y_i}{\sum_{i=1}^k (y_i)} \times 100$	Dallmeier et al. (1992); Misra (1968)
Relative Dominance (RDo)	$RD_o = \frac{d_i}{\sum_{i=1}^k (d_i)} \times 100$	Dallmeier et al. (1992); Misra (1968)
Importance Value Index (IVI)	$IVI = RD + RF + RD_o$	Dallmeier et al. (1992); Shukla and Chandel (2000)
Shannon-Wiener Index (H)	$H = - \sum_{i=1}^N P_i (\ln P_i)$	Shannon and Wiener (1963)
Simpson Index (CD)	$CD = \frac{\sum_{i=1}^N n_i (n_i - 1)}{N(N - 1)}$	Simpson (1949)

Notes: a = Total number of individuals of a species in all the plots; b = Total number of plots; c = Total number of plots in which the species occurs; d = Total basal area of a species in a plot; e = Diameter at breast height in meter; k = Total number of plots; N = total number of individuals of all the species; n = Number of individuals of a species; P = n/N; S = Total number of species

Results and Discussion

A total of 783 individuals of plant species was recorded from 1.23 ha plots of the Teak plantation which represents 78 plant species, including 34 trees, 19 shrubs, and 25 herbs belonging to 70 genera and 40 families. The collected number of the total individual of plant species were less than the number reported by Feroz et al. (2014) from the Kaptai National Park and by Mohajan et al. (2016) from Kaptai deer breeding centre of the Kaptai Reserve forest, Bangladesh. However, the total plant species noticed during the present study are more than observed by Rahman et al. (2016) and Feroz et al. (2014) from Kaptai National park, but less tree species than observed by Chowdhury et al. (2017) from Sitapahar of Kaptai reserve forest.

The dominant family in our study areas was Rubiaceae with 6 species, followed by Araceae, Euphorbiaceae and Verbenaceae (5 species each), Bignoniaceae, Caesalpiniaceae, Dilleniaceae, Fabaceae, Lauraceae, Meliaceae and Urticaceae (3 species each); Leeaceae, Myrtaceae, Anacardiaceae, Malvaceae, Moraceae, Orchidaceae and Rutaceae. Remaining families (22, 55%) were represented by a single species. Out of 70 genera, 63 (81%) consisted of a single species. *Senna* was the most specious genera with three species, followed by *Stereospermum*, *Litsea*, *Leea*, *Syzygium* and *Ixora*. Out of 78 species, single individuals represented 10 species (7.8%) (Tab. 2).

In case of trees, Euphorbiaceae was the richest family with 4 species while in herbs it was Araceae with 5 species and in shrubs Rubiaceae and Verbenaceae (3 species each)

Table 2. Different families of entire plantation with number of species and genus at Teak plantation in Karnaphuli Range, Kaptai, Rangamati, Bangladesh

Family	Species	Genus
Anacardiaceae	2	2
Araceae	5	5
Bignoniaceae	3	2
Caesalpiniaceae	3	2
Dilleniaceae	3	2
Euphorbiaceae	5	5
Fabaceae	3	3
Lauraceae	3	2
Leeaceae	2	1
Malvaceae	2	2
Meliaceae	3	3
Moraceae	2	2
Myrtaceae	2	1
Orchidaceae	2	2
Rubiaceae	6	5
Rutaceae	2	2
Urticaceae	3	2
Verbenaceae	5	5
Other 21 families	1	1

Table 3. Plant habit wise different families with number of species and genus of Teak plantation at Karnaphuli Range in Kaptai, Rangamati, Bangladesh

Tree		Herb		Shrubs	
Family	No of Species	Family	No of Species	Family	No of Species
Euphorbiaceae	4	Araceae	5	Rubiaceae	3
Bignoniaceae	3	Fabaceae	2	Verbenaceae	3
Meliaceae	3	Orchidaceae	2	Leeaceae	2
Anacardiaceae	2	Rubiaceae	2	Rest families	1
Dilleniaceae	2	Urticaceae	2		
Lauraceae	2	Rest families	1		
Moraceae	2				
Myrtaceae	2				
Verbenaceae	2				
Rest families	1				

were the richest families in species (Tab. 3). Mohajan et al. (2016) in Kaptai deer breeding centre, also revealed the Euphorbiaceae family was represented by the highest number of species. Feroz et al. (2014), also noticed that Euphorbiaceae and Moraceae were the most species-rich families in Rampahar of Kaptai National park area. The dominance of this family indicates a good adaptation of its species to the existing environmental conditions at the study site as compared to species of other families.

Among the recorded species, threatened species were 9% (3% Endangered and 6% Vulnerable). Beside these, 72% plants were in the category Least Concern, 10% species were not evaluated, 6% near threatened and 3% were data deficient (Ahmed et al. 2009) (Fig. 1). The recorded herbaceous species *Crepidium biauratum* and *Hedyotis thomsonii* are considered endangered (EN), *Diospyros ramiflora*, *Homalomena aromatic*, *Hopea odorata*, *Ixora spectabilis* and *Xerospermum laevigatum* are considered Vulnerable (VU) (Ahmed et al. 2008b, 2009; Ara et al. 2013).

Tree species

At the present study site, the dominant tree species *Tectona grandis* possess the highest 'D', 'F', IVI and 'A', (Tab. 4) with the highest dispersal rate and per unit, area covered as compared to other species. In case of tree species, the total value of D and A was found to be more than the one observed by Sobuj & Rahman (2011a) from the Khadimnagar

National Park of Bangladesh. *Casearia tomentosa*, *Stereospermum suaveolens* and *Syzygium grande* exhibited lowest D, A, F, IVI, H and CD with less ground covered. Equivalent values of different parameters with similar dispersal rates were found in the case of many species. The D of whole trees was observed in the range of 0.78-310.94 and that of A of 01-12.44, F of 3.13-100.00 and IVI of 1.310-178.541. The values of H and CD observed at the present study site are less than noticed by Rahman et al. (2016) of Kaptai National park area, Kaptai reserve forest, Bangladesh due to more intervention of human being and xeric types of environmental condition.

The highest BA was noticed in *Tectona grandis*, which indicates that this species is better adapted to the climatic condition. The lowest value of BA was found in *Casearia tomentosa* followed by *Chukrasia tabularis*, *Cinnamomum pachyphyllum* and *Stereospermum suaveolens*, indicating reduced growth and less basal area covered by these species. The total value (1.486) of the Shannon's diversity index in the case of trees at the study site was less than at other sites in KNP (Feroz et al. 2014) and Kaptai deer breeding centre of the Karnaphuli range (Mohajan et al. 2016). Similarly, the value of CD was lower than the one observed by Rahman et al. (2016) in the Kaptai National Park area.

Tree individuals' distribution among different diameter at breast height (DBH) classes (Fig. 2) showed a reverse J-shaped curve, typical for most undisturbed tropical and temperate forests (Campbell et al. 1986).

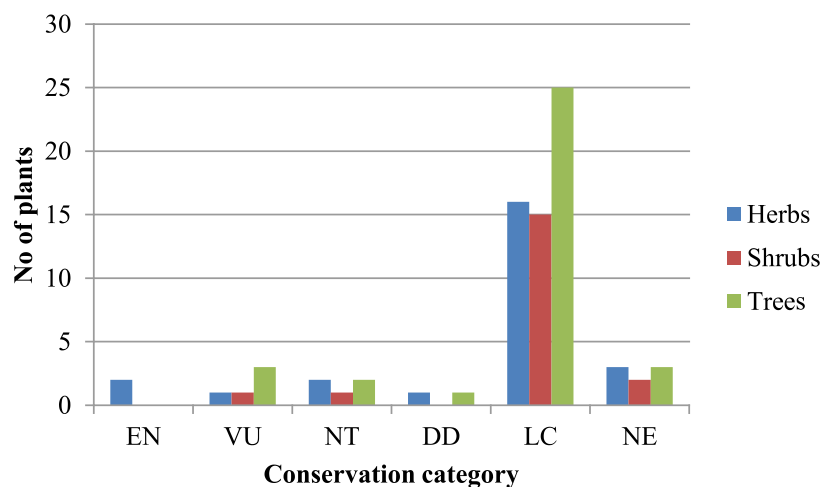


Figure 1. Conservation status of the recorded plant species of teak plantation at Karnaphuli range in Kaptai, Rangamati, Bangladesh (EN-Endangered; VU-Vulnerable; NT-Near threatened; DD-Data deficient; LC-Least concern; NE-Not evaluated)

Table 4. The values of different parameters of tree species at Karnaphuli range in Kaptai, Rangamati, Bangladesh

Scientific name	Family	D	F	A	IVI	AF	H	CD	BA
<i>Aegle marmelos</i> (L.) Corr.	Rutaceae	0.13	6.25	2	3.50	0.32	0.036	0.007	0.12
<i>Anthocephalus cadamba</i> (Roxb.) Miq.	Rubiaceae	0.13	6.25	2	3.56	0.32	0.036	0.007	0.14
<i>Aphanamixis polystachya</i> (Wall.) R.N.Parker	Meliaceae	0.09	3.13	3	2.04	0.96	0.029	0.005	0.09
<i>Artocarpus lacucha</i> Buch.-Ham.	Moraceae	0.28	6.25	4.5	4.96	0.72	0.068	0.016	0.24
<i>Baccaurea ramiflora</i> Lour	Phyllanthaceae	0.19	6.25	3	5.36	0.48	0.049	0.011	0.45
<i>Casearia tomentosa</i> Roxb.	Flacortiaceae	0.03	3.13	1	1.31	0.32	0.012	0.002	0.01
<i>Chukrasia tabularis</i> A. Juss	Meliaceae	0.09	3.13	3	1.80	0.96	0.029	0.005	0.03
<i>Cinnamomum pachyphyllum</i> Kosterm.	Lauraceae	0.06	3.13	2	1.61	0.64	0.021	0.004	0.03
<i>Dillenia indica</i> L.	Dilleniaceae	0.09	3.13	3	1.84	0.96	0.029	0.005	0.04
<i>Dillenia pentagyna</i> Roxb.	Dilleniaceae	0.16	6.25	2.5	4.13	0.40	0.043	0.009	0.22
<i>Diospyros ramiflora</i> Roxb.	Ebenaceae	0.06	6.25	1	3.16	0.16	0.021	0.004	0.13
<i>Holigrana longifolia</i> Buch.-Hum. ex Roxb.	Anacardiaceae	0.16	6.25	2.5	5.95	0.40	0.043	0.009	0.62
<i>Hopea odorata</i> Roxb.	Dipterocarpaceae	0.09	3.13	3	2.17	0.96	0.029	0.005	0.11
<i>Lagerstroemia</i> sp.	Lythraceae	0.34	15.63	2.2	9.59	0.14	0.079	0.020	0.46
<i>Litsea glutinosa</i> Lour.	Lauraceae	0.22	6.25	3.5	4.32	0.56	0.056	0.013	0.18
<i>Macaranga denticulata</i> (Blume.) Muell. Arg.	Euphorbiaceae	0.09	3.13	3	1.84	0.96	0.029	0.005	0.04
<i>Mallotus tetracoccus</i> (Roxburgh) Kurz	Euphorbiaceae	0.16	6.25	2.5	3.62	0.40	0.043	0.009	0.11
<i>Myristica linifolia</i> Roxb.	Myristicaceae	0.16	6.25	2.5	7.51	0.40	0.043	0.009	0.96
<i>Pagenalia longifolia</i> (Wild.) K. Schum.	Bignoniaceae	0.06	3.13	2	1.65	0.64	0.021	0.004	0.04
<i>Palaquium polyanthum</i> (Wall. ex G. Don.) Baill	Sapotaceae	0.50	18.75	2.67	10.29	0.14	0.103	0.029	0.17
<i>Protium serratum</i> (Wall. ex Coelbr.) Engl	Burseraceae	0.31	9.38	3.33	6.88	0.36	0.073	0.018	0.38
<i>Saraca asoca</i> (Roxb.) Willd.	Caesalpiniaceae	0.09	3.13	3	1.84	0.96	0.029	0.005	0.04
<i>Spondias indica</i> (L.f.) Kurz	Anacardiaceae	0.06	6.25	1	3.16	0.16	0.021	0.004	0.13
<i>Stereospermum personatum</i> (Hassk.) Chatt.	Bignoniaceae	0.06	3.13	2	2.25	0.64	0.021	0.004	0.17
<i>Stereospermum suaveolens</i> (Roxb.) DC.	Bignoniaceae	0.03	3.13	1	1.42	0.32	0.012	0.002	0.03
<i>Streblus asper</i> Lour.	Moraceae	0.09	3.13	3	2.09	0.96	0.029	0.005	0.10
<i>Suregada multiflora</i> (A. Juss.) Baill.	Euphorbiaceae	0.09	3.13	3	2.17	0.96	0.029	0.005	0.11
<i>Swietenia mahagoni</i> (L.) Jacq.	Meliaceae	0.06	3.13	2	1.89	0.64	0.021	0.004	0.09
<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	0.19	6.25	3	5.66	0.48	0.049	0.011	0.52
<i>Syzygium grande</i> (Wight) Walp.	Myrtaceae	0.03	3.13	1	1.53	0.32	0.012	0.002	0.06
<i>Tectona grandis</i> L.f.	Verbenaceae	12.44	100.00	12.44	178.54	0.12	0.231	0.728	15.44
<i>Trewia nudiflora</i> L.	Euphorbiaceae	0.19	6.25	3	4.15	0.48	0.049	0.011	0.19
<i>Vitex peduncularis</i> Wall. ex Schauer	Verbenaceae	0.25	9.38	2.67	5.55	0.28	0.062	0.015	0.17
<i>Xerospermum laevigatum</i> Radlk.	Sapindaceae	0.09	3.13	3	2.66	0.96	0.029	0.005	0.23
	Total	17.07	284.47	94.31	300.00	18.48	1.486	0.997	21.85

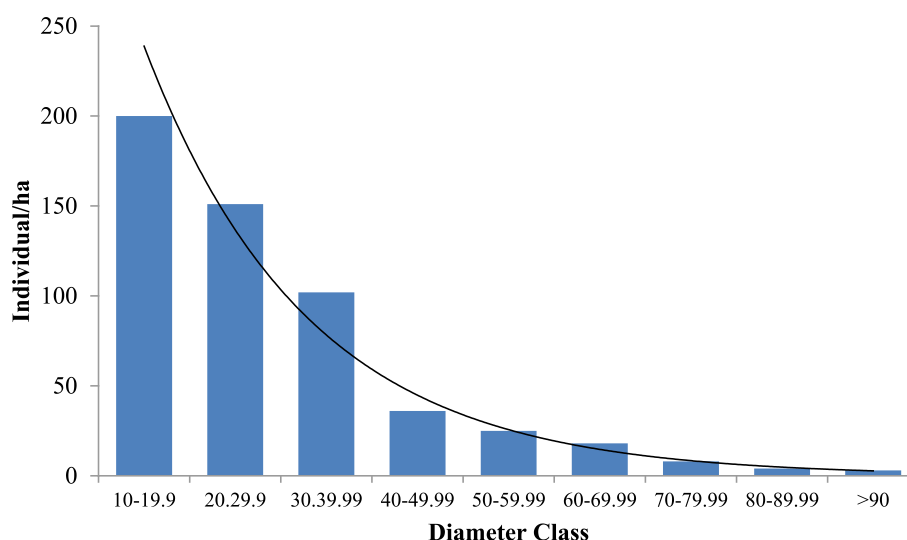


Figure 2. Distribution of number of individual per hectare of standing trees by diameter class (cm) of Teak plantation at Kanaphuli range in Kaptai, Rangamati, Bangladesh

Table 5. The values of different parameters of shrub species at Karnaphuli range in Kaptai, Rangamati, Bangladesh

Scientific name	Family	D	F	A	IVI	A/F	H	CD
<i>Chromolaena odorata</i> L.	Asteraceae	0.44	12.50	3.5	17.92	0.28	0.251	0.013
<i>Clerodendrum viscosum</i> Vent.	Verbenaceae	0.19	12.50	1.5	11.25	0.12	0.150	0.002
<i>Datura metel</i> L.	Solanaceae	0.16	9.38	1.67	8.85	0.18	0.132	0.001
<i>Ixora lanceolata</i> Lam.	Rubiaceae	0.09	6.25	1.5	5.63	0.24	0.092	0.000
<i>Ixora spectabilis</i> Wall. ex G. Don	Rubiaceae	0.16	6.25	2.5	7.29	0.40	0.132	0.001
<i>Lantana camera</i> L.	Verbenaceae	0.72	50.00	1.44	44.17	0.03	0.317	0.035
<i>Leea aequata</i> L.	Leeaceae	0.16	9.38	1.67	8.85	0.18	0.132	0.001
<i>Leea macrophylla</i> Roxb. ex Hornem	Leeaceae	0.09	6.25	1.5	5.63	0.24	0.092	0.000
<i>Litsea monopetala</i> (Roxb.) Persoon	Lauraceae	0.22	18.75	1.17	15.21	0.06	0.166	0.003
<i>Maesa ramentacea</i> (Roxb.) A. DC.	Myrsinaceae	0.09	6.25	1.5	5.63	0.24	0.092	0.000
<i>Microcos paniculata</i> L.	Malvaceae	0.22	9.38	2.33	10.52	0.25	0.166	0.003
<i>Murraya koenigii</i> (L.) Spreng	Rutaceae	0.06	3.13	2	3.23	0.64	0.068	0.000
<i>Mussaenda roxburghii</i> Hook.f.	Rubiaceae	0.03	3.13	1	2.40	0.32	0.040	0.000
<i>Premna integrifolia</i> L.	Verbenaceae	0.09	6.25	1.5	5.63	0.24	0.092	0.000
<i>Sarcochlamys pulcherrima</i> Guadich.	Urticaceae	0.03	3.13	1	2.40	0.32	0.040	0.000
<i>Senna alata</i> (L.) Roxb.	Caesalpiniaceae	0.13	6.25	2	6.46	0.32	0.113	0.001
<i>Senna occidentalis</i> (L.) Link.	Fabaceae	0.16	6.25	2.5	7.29	0.40	0.132	0.001
<i>Tabernaemontana corymbosa</i> Roxb. ex Wall.	Apocynaceae	0.16	6.25	2.5	7.29	0.40	0.132	0.001
<i>Tetracera sarmentosa</i> (L.) Vahl.	Dilleniaceae	0.56	18.75	3	24.35	0.16	0.285	0.021
	Total	3.76	200.03	35.78	200.00	5.02	2.624	0.083

It depicts the progressive decline of tree individuals in larger tree size classes. The number of species and tree individuals was found to decrease constantly in the higher DBH categories with few exceptions. The number of species, tree individuals and their percentage were the highest (23 species; 200 individuals and 36.56%) in 10-19.9 cm DBH range and the lowest (1 species, 3 individuals and 0.55%) in >90 cm DBH range (Fig 2). The reason was the illicit felling of mature and economically vital trees in the Teak woodland. The higher

number of trees in lower size categories also indicates copious natural regeneration.

Shrub species

The shrub species at the study site were more densely distributed than trees. *Lantana camera* was found to have maximum 'D', 'F', IVI, SD and CD, and is considered as the dominant species (Tab. 5). *Chromolaena odorata* had the maximum 'A' with very a high

per unit area of distribution. The lowest value of 'D' and IVI was reflected by *Mussaenda roxburghii* and *Sarcochlamys pulcherrima*, which means that per unit area and the dominance of this species is very less.

The values of 'D' of entire shrubs lie between 0.031-0.719 and that of 'A' 1-3.5, 'F' 3.13- 50.00, IVI 2.40-44.17, SD 0.0399-0.3166 and CD 0.0006- 0.0354. The values of Simpson's and Shannon's index (2.624) in case of shrubs are more than those observed (2.56) by Sobuj & Rahman (2011a) from the Khadimnagar National Park, Sylhet, Bangladesh under tropical evergreen and semi-evergreen biogeographic zone.

Herb species

The dominant species among herbs was *Heliotropium indicum*, based on the highest value of 'D', 'F', IVI, etc. (Tab. 6). The lowest

values of IVI found for *Cymbopogon citratus*, *Amorphophallus campanulatus*, *Crotalaria pallida*, *Elatostema papillosum* and *Senna tora* show that these species are fewer in numbers and have smaller dispersal rate. The value of 'A' at the present site (that is, per unit area) for all trees, shrubs and herbs is found to be somehow similar, except for *Tectona grandis*. However, the herbs bare much difference in occurrence from one another, which means that the distributional composition of herbs is more.

The herb species were found in superior position than trees and shrubs in our study areas. The values of 'D' among herbs are observed between 0.03-0.47 and that of 'A' 01-07, 'F' 3.13-37.50, IVI 2.074-27.501 and CD 4E-09 to 0.016. The observed value of the Shannon's index (2.944) was found to be less than observed by Sobuj & Rahman (2011a) in the Khadimnagar National Park (3.27) and similar with the values found by AlAmin et al.

Table 6. The values of different parameters of herb species at Karnaphuli range in Kaptai, Rangamati, Bangladesh

Scientific Name	Family	D	F	A	IVI	AF	H	CD
<i>Acalypha indica</i> L.	Euphorbiaceae	0.06	3.13	2	2.94	0.64	0.070	0.000
<i>Aglaonema hookerianum</i> Schott.	Araceae	0.16	6.25	2.5	6.76	0.40	0.136	0.002
<i>Alocasia fornicata</i> (Roxb.) Schott.	Araceae	0.06	3.13	2	2.94	0.64	0.070	0.000
<i>Amaranthus spinosus</i> L.	Amaranthaceae	0.22	9.38	2.33	9.70	0.25	0.170	0.003
<i>Amorphophallus campanulatus</i> (Roxb.) Bl.	Araceae	0.03	3.13	1	2.07	0.32	0.041	0.000
<i>Argemone mexicana</i> L.	Papaveraceae	0.22	3.13	7	7.29	2.24	0.170	0.003
<i>Aristolochia tagala</i> Cham.	Aristolochiaceae	0.06	3.13	2	2.94	0.64	0.070	0.000
<i>Chenopodium album</i> L.	Chenopodiaceae	0.09	9.38	1	6.22	0.11	0.095	0.000
<i>Crepidium bauritum</i> (Lindl.) D.L.	Orchidaceae	0.41	12.50	3.25	16.12	0.26	0.246	0.012
<i>Crotalaria pallida</i> Aiton.	Fabaceae	0.03	3.13	1	2.07	0.32	0.041	0.000
<i>Curculigo orchoides</i> Gaertn.	Liliaceae	0.09	9.38	1	6.22	0.11	0.095	0.000
<i>Cymbopogon citratus</i> (DC. ex Nees) Stapf	Poaceae	0.03	3.13	1	2.07	0.32	0.041	0.000
<i>Desmodium heterocarpon</i> (L.) DC.	Fabaceae	0.28	28.13	1	18.67	0.04	0.199	0.005
<i>Elatostema papillosum</i> Wedd.	Urticaceae	0.03	3.13	1	2.07	0.32	0.041	0.000
<i>Fleurya interrupta</i> (L.) Gaudich	Urticaceae	0.22	21.88	1	14.52	0.05	0.170	0.003
<i>Geodorum densiflorum</i> (Lam.) Schltr	Orchidaceae	0.13	12.50	1	8.30	0.08	0.117	0.001
<i>Hedyotis thomsonii</i> Hook. f.	Rubiaceae	0.06	3.13	2	2.94	0.64	0.070	0.000
<i>Heliotropium indicum</i> L.	Boraginaceae	0.47	37.50	1.25	27.50	0.03	0.266	0.016
<i>Homalomena aromatica</i> (Spreng.) Schott.	Araceae	0.09	9.38	1	6.22	0.11	0.095	0.000
<i>Mimosa pudica</i> L.	Mimosaceae	0.16	15.63	1	10.37	0.06	0.136	0.002
<i>Oldenlandia corymbosa</i> L.	Rubiaceae	0.22	21.88	1	14.52	0.05	0.170	0.003
<i>Portulaca oleracea</i> L.	Portulacaceae	0.19	18.75	1	12.45	0.05	0.154	0.002
<i>Senna tora</i> (L.) Roxb.	Caesalpiniaceae	0.03	3.13	1	2.07	0.32	0.041	0.000
<i>Sida acuta</i> Burm. f.	Malvaceae	0.13	3.13	4	4.68	1.28	0.117	0.001
<i>Typhonium trilobatum</i> L.	Araceae	0.13	12.50	1	8.30	0.08	0.117	0.001
Total		3.59	259.38	43.33	200.00	9.35	2.944	0.056

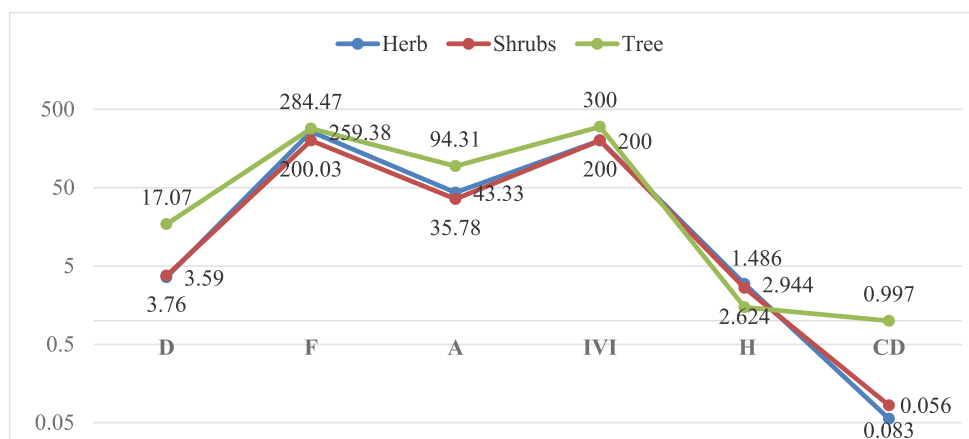


Figure 3. The values of different parameters of entire plantation at Karnaphuli range in Kaptai, Rangmati, Bangladesh

(2007) in the forested northeastern region of Bangladesh (2.9), which is likely due to the similar environmental conditions and human interventions.

The species richness at the site was observed to be the highest in herbs (25), followed by trees (34) and lowest in shrubs (19). The total value of 'D' among different species (herbs, shrubs and trees) reveals the strength and distributional composition of one species relative to another and was found to be the highest in the case of trees, followed by shrubs and lowest in herbs (Fig. 3). The per unit area on the basis of total 'A' value came out highest in trees followed by herbs and shrubs. The dominant species at the study site among trees was found to be *Tectona grandis*, *Palaquium polyanthum*, *Lagerstroemia* sp., *Myristica linifolia* and *Protium serratum* and among shrubs the dominant species was *Lantana camera* followed by *Tetracera sarmentosa*, *Chromolaena odorata*, *Litsea monopetala* and *Clerodendrum viscosum*. The *Heliotropium indicum* was noticed as a dominant species among herbs, followed by *Desmodium heterocarpon*, *Crepidium bauritum*, *Fleurya interrupta* and *Oldenlandia corymbosa*.

The results indicate that the majority of species show contagious distribution followed by random distribution. The highest value was recorded in case of trees (100%). Most of the herbs and shrubs also showed contagious distribution, except *Lantana camera* (0.03) among shrubs and in *Heliotropium indicum* (0.03) and *Desmodium heterocarpon* (0.04) among herbs. The dispersal rate of entire study area was found to be the highest in trees, followed by herbs and lowest in shrubs. A similar result was noticed by Sobuj &

Rahman (2011b) in the Khadimnagar Nation Park for shrubs and herbs.

Based on the higher value of the Shannon's index (H), the herbs conveyed a large number of species with a small number of individuals, followed by shrubs and trees. The value of this index is found to be higher than the value recorded in the north eastern region of Bangladesh by AlAmin et al. (2007). The Simpson's index indicates that the species diversity is highest amongst herbs, followed by shrubs and trees (Fig. 3). The trees and shrubs are having a closer pattern of distribution of the present study site, but little different from herbs.

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