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Species composition and forest structure in tropical moist deciduous forest of Bangladesh—a case study in Thakurgaon

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Abstract This study was conducted in the tropical moist deciduous forest in Bangladesh to describe the species composition, diversity, and the forest structure. There were three plots established in Ranishonkoil, Ruhia, and Baliadangi forest beat in Thakurgaon. A total of 126 tree species, 1,991 stems (663 ha^{-1}) of ≥10-cm girth were listed. Tree communities in these forest region differed in dominance, composition, diversity, and structure; and tree stand density varied from 651 to 685 ha^{-1}. Species diversity (H^1) ranges from 3.11 to 3.48. Meliaceae, Myrtaceae, and Rubiaceae were the most abundant families within the three plot area. Study site 2 is more diverse at spatial scale and taxonomic levels due to high rainfall and favorable edaphic condition. This study will help the foresters as baseline information for monitoring and sustaining diversity of tropical moist deciduous forests in Bangladesh.

Keywords Species diversity · Structure · Dominance · Importance value index

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Introduction

Bangladesh is one of the most densely populated countries of the world with a population of 133.4 million; density is about 904/km^2 and population growth is the most serious problem of the country (Anonymous Bangladesh Economic 2003). The majority of land is flat and formed by river alluvium from the Ganges and the Brahmaputra and their tributaries. The eastern and northeastern parts of the country consist of hills alternating with broad valleys (Das 1990). The total area of the country is 14.4 millionha of which 2.46 millionha is covered by forests distributed all over the country (Table 1). The natural forests of Bangladesh consist of three major vegetation types occurring on three distinctly different land types (Hassan 1994). Species diversity is the number of different species in a particular area weighted by some measure of abundance such as number of individuals or biomass. It differs from place-to-place. Bangladesh is rich in biodiversity; due to anthropogenic activities and replaced by inferior species and change of land use pattern, the primary forest area are disappearing. Studies from forest survey of Bangladesh showed that an average of more than 70% of the forest is affected by overpopulation and their activities (BBS 2003). Forest ecosystem dynamics and conservation depends on the understanding of species composition and diversity. Information on floral composition, diversity, and biomass are absolutely essential in understanding the forest ecosystem. It works as a tool to estimate the level of adaptation to the environment and their ecological significance (Nath et al. 1998). Tropical moist deciduous forests are enriched with economically important multi-purposes tree species such as fruit, timber, etc. Vegetation composition, diversity of species, and their habitats are well understood for other tropical forest types compared to moist deciduous forests.

Table 1 Forest types of Bangladesh

Forest Type	Location	Area (million ha)	Remarks
Tropical Moist Hill Forest	Eastern part (Chittagong Hill Tracts and Sylhet)	0.67	Managed under the control of Forest Department
Unclassed State Forest (USF)	Hill Tracts Districts	0.73	Once rich with Dipterocarps and associates but now degraded and under control of district administration
Tropical Moist Deciduous Forest	Central and Northwest	0.12	Indigenous Sal forest are converting to exotic short rotation plantations
Mangrove Forests	South-West	0.57	Well Known Sundarban Mangrove natural forests
Coastal Forest	All along the coast	0.10	Mangrove plantations mainly with *Sonneratia apetala*
Village Forests	All over the country	0.27	Homestead Forests of individual villagers all over the country

The floristic composition of the forests of Bangladesh is rich and has been described by several authors; e.g., Khan and Afza (1968) briefly gave the preliminary floristic report on Teknaf forest, Alam (1988) about Sylhet forests, and Alam (1995) about moist deciduous forests area. In comparison to the moist deciduous and evergreen and semi-evergreen hill forests, the flora of the Sundarban mangroves did not show much heterogeneity in floral composition (Chaffey et al. 1985). However altogether, about 5,700 species of angiosperms and 1,500 species of fauna will be available in the country, but recent findings show that the populations of some of the species have declined to about a half (Khan 1996). The tropical moist deciduous forests in Thakurgaon in Bangladesh, also known as "inland sal forests", cover relatively small areas distributed over the inland plain area (Alam 1995). They are predominantly composed of sal (*Shorea robusta*) occurring in pure patches, sometimes associated with korai (*Albizia* spp.) in the canopy and mahogany (*Swietenia mahagon*), neem (*Azadirachta indica*), and other multipurpose tree species. More than half of these forests are located in the Dhaka, Mymensingh, and Dinajpur forest division. They have been subjected to considerable illicit fellings and encroachments due to their location in densely populated area. Compared to other tropical forest types, this forest is the most exploited and endangered ecosystems of the biosphere (Momin et al. 1990).

Bangladesh is a small country of about 14.4 million hectares of land area of which some two million hectares or about (17%) are under forest cover (BBS 2003). It is established that the forest cover is reducing at an annual rate of 2.5% (USAID 1990). Because of reduction in the total forest area and also the inadequacy of tree planting and of effective management of forests, the forest cover at its present level is too small for the country's overall demand for timber, fuel, food and fooder, and maintaining ecological balance of the country (Ahmed 1987). Bangladesh has been identified as one of the countries with perhaps the highest level of vulnerability to climate change (McCarthy et al. 2001). Climate is a key factor which determines the distribution of plants; and as when temperature and rainfall patterns change, the ranges of both animal and plant species change. Many plant and animal species widely distributed in the past have either been going extinct or can only be found in some localized areas at very low population densities. The issues of conservation and protection of biological diversity have so far had a low priority in Bangladesh (Hossain 2001); especially since the northern part is always ignored by the decision-making authority and researches (Zaman and Katoh 2009). Thus, the objective of the present study is to assess the present status of tree species and natural regeneration of the tree species in a remnant natural forest of Bangladesh; also to determine the structure and floristic composition of tree diversity in Thakurgaon, Bangladesh.

Materials and methods

Study area

The study area was located between 25° 57′ to 25° 57′ N and 88° 15′ to 88° 25′ E (Fig. 1) in the northern part of Bangladesh and is about 2,497.92 km^2. It is bordered by India on its west and north sides, it is a part of the Himalayan plain land. Thakurgaon district is located far from the divisional towns as well as the central part of Bangladesh. The climate is mainly drought and monsoon usually begins in June and ends in September. The mean annual rainfall range is between 1,500 and 1,800 mm (BBS 2006). The temperature varies on an average from 37°C and 26°C in summer, 28°C and 10°C in winter. There are five forest beats (lowest administrative units) in Thakurgaon forest range (Ranishonkoil, Baliadangi, Horipur, Pirgonj, and Ruhia; Fig. 1).Three 1-ha plots area was selected at three different beats/sites: site 1 is located in Horipur beat, site 2 is located in Ruhia beat, and site 3 is

Fig. 1 The study area: Horipur (*1*), Ruhia (*2*), Baliadangi (*3*), in Thakurgaon district, Bangladesh (GIS image, source: Bangladesh Meteorological Department)

located in Baliadangi beat in Thakuragon forest ranges (administrative units).

Field sampling

Phytosociological data were collected in three 100×100-m plots which were divided into 20×20-m subplots and were systematically surveyed for all trees ≥10-cm girth at breast height (GBH) and was above 130 cm from the ground. The collection period was April 2008 to June 2008 in Horipur-Ruhia-Baliadangi in Thakurgaon, Bangladesh. Thus, data were obtained from a total of 60 subplots (total=3 ha). All plots sampled were representative of the most common vegetation types in Thakurgaon. The species were identified with the help of the Department of Agricultural Extension.

Data analysis

The vegetation data were quantitatively analyzed for basal area, relative density, relative frequency, and relative dominance (Phillips 1959). The importance value index (IVI) for the tree species was determined as the sum of the relative frequency, relative density, and relative dominance (Cottam and Curtis 1956).

$$\begin{aligned}\text{Basal area}\left(\text{m}^2\right) &= \text{area occupied at breast height}(1.3\text{m})\\ &= C^2/4\text{p or } 0.0796\\ &\quad \times C^2(\text{where } C \text{ is the circumference}).\end{aligned}$$

$$\begin{aligned}\text{Relative density} &= \text{no of the trees of species}\\ &\quad /\text{total number of trees of all species}\\ &\quad \times\ 100\end{aligned}$$

$$\begin{aligned}\text{Relative frequency} &= \text{no of time species occurs}\\ &\quad /\text{total number of species}\ \times\ 100\end{aligned}$$

$$\begin{aligned}\text{Relative dominance} &= \text{total basal area of a species}\\ &\quad /\text{total basal area for all species}\\ &\quad \times\ 100\end{aligned}$$

$$\begin{aligned}\text{IVI} &= \text{sum of relative density} + \text{relative frequency}\\ &\quad + \text{relative dominance}\end{aligned}$$

$$\text{Species diversity of each forest types was determined using Shanon} - \text{Weiner index}\left(\text{H}^1\right) = -\text{sum}\{(\text{ni}/\text{N})1\text{n}(\text{ni}/\text{N})\}$$

(Shannon and Wiener 1949; Odum 1971). Where, ni=IVI of individual species; *N*=IVI of all species.

Local diversity was defined as the number of species found in a hectare. Regional diversity of each area derived independently of plot data.

Results and discussions

Species composition

A total of 126 tree species were recorded within 3-ha plots area, responding 89 genera in 40 families. The mean stem density of 663 stems ha^{-1} and range of 651–685 stems ha^{-1} in the forests of Northern part of Bangladesh. The tree diversity assessed by the Shannon–Weiner index (H^1) which was 3.19, 3.48, and 3.11 for the site 1, 2, and 3, respectively. Plot-wise tree species richness was 59 for site 1, 64 for site 2, and 57 for site 3 with major differences between the plots (Table 2). Site 2 forests are more diverse at spatial scale and all taxonomic levels than their counterparts followed by 1 and 3 (Table 2). Within the three plot areas, the most abundant families were Meliaceae, Myrtaceae, and Rubiaceae. An obvious variation in representation of tree species and the proportion of dominant species in the three sites can directly be attributed to rainfall distribution and favorable edaphic conditions. The study results were similar in comparison with the study of Alam (1995) in diversity in the woody flora of Sal forest of Bangladesh. The most frequently occurring species in three sites was *S. mahagoni*, *Magnifera indica*, and *Artocarpus heterophyllus*. In site 1 and 2, some of moisture-indicating species is prevalent, i.e., *Dalbargia sissoo*, *A. indica*, *Pterocarpus marsupium*, and *Anthocephallus chinensis.* Where as in site 3, species composition posses comparatively indicating dry habitats and *Cassia fistula*, *Terminalia arjuna*, *Albizia chinensis*, and *Gmelina aroba* were predominant (Table 3).

There was a total 1,991 individuals representing 40 families in the three plots area. The common tree species in the three sites was *S. mahagoni*, *M. indica*, and *A. heterophyllus* which is commonly found all over the moist deciduous forest for their multipurpose value. These three species had the most individuals in all plots also. Species similarity between different sites was using presence/absence data. Of the species recorded, 58% was found similar between sites 1 and 2. Sites 1 and 3 had 37% common species. The top ten predominant species with relative dominance, relative density, relative frequency, and IVI were given in Table 3. In this study, it was found that the forest area of Thakurgaon was rich in plant diversity, especially site 2. Most of the tree species were randomly distributed. The relative density of species per unit area was maximum for *M. indica* 19.2 in site 1, *A. heterophyllus* 21.2, and 21.46 in sites 2 and 3, respectively. The relative dominance which is a coverage value of a species was found to by maximum for *A. heterophyllus* (20.78)

Table 2 Combined particulars of species inventory in the study sites

Description	Site 1	Site 2	Site 3	Total
No of tree species	59	64	57	126
No of genera	48	51	41	89
No of families	22	24	19	40
Density (stems ha^{-1})	655	685	651	1,991
Species diversity index (H^1)	3.19	3.48	3.11	–
No of shrub species	24	27	21	35
No of herb species	61	56	63	103
No of climber species	21	17	19	26

Table 3 The family name, relative density, dominancy, frequency, basal area, IVI, and species diversity of different species in the study sites

	RD	RDo	RF	Basal area	IVI	Family	Diversity index
Site 1							
Swietenia mahagoni	18.7	17.1	7.3	3.18	42.4	Meliaceae	−0.131
Magnifera indica	19.2	14.7	7.2	3.43	41.1	Anacardiaceae	−0.156
Artocarpus heterophyllus	16.02	20.78	19.1	2.19	56.57	Moraceae	−0.120
Shorea robusta	1.5	2.5	3.0	2.55	7.0	Dipterocarpaceae	−0.090
Dalbargia sissoo	8.3	8.5	3.8	1.25	20.6	Fabaceae	−0.126
Azadirachta indica	14.6	14.4	17.2	3.83	46.2	Meliaceae	−0.065
Pterocarpus marsupium	1.9	4.8	5.0	0.21	11.7	Fabaceae	−0.037
Anthocephallus chinensis	4.7	2.4	2.8	2.13	9.9	Rubiaceae	−0.123
Eucalyptus tereticornis	1.7	2.0	3.4	0.36	7.1	Myrtaceae	−0.040
Syzygium cumini	7.88	6.29	5.1	1.95	19.3	Myrtaceae	−0.100
Site 2							
Swietenia mahagoni	19.4	16.3	8.9	3.27	44.5	Meliaceae	−0.139
Magnifera indica	16.7	5.3	6.1	3.86	28.1	Anacardiaceae	−0.128
Artocarpus heterophyllus	21.2	14.5	6.8	2.1	42.4	Moraceae	−0.138
Shorea robusta	2.6	2.5	3.1	2.9	8.3	Dipterocarpaceae	−0.089
Dalbargia sissoo	7.3	5.8	4.2	1.79	17.3	Fabaceae	−0.118
Azadirachta indica	8.1	8.1	9.7	2.65	25.9	Meliaceae	−0.082
Pterocarpus marsupium	1.4	2.3	3.4	0.42	7.0	Fabaceae	−0.065
Anthocephallus chinensis	12.35	11.59	15.16	1.95	39.11	Rubiaceae	−0.090
Eucalyptus tereticornis	4.8	2.4	2.2	0.27	9.5	Myrtaceae	−0.061
Syzygium cumini	5.61	5.21	7.24	1.55	18.07	Myrtaceae	−0.130
Site 3							
Swietenia mahagoni	14.6	14.4	17.2	3.12	46.2	Meliaceae	−0.145
Magnifera indica	17.1	8.2	9.7	3.42	35	Anacardiaceae	−0.132
Artocarpus heterophyllus	21.46	16.02	8.82	2.49	46.3	Moraceae	−0.141
Cassia fistula	7.86	5.4	7.24	0.67	20.51	Caesalpiniaceae	−0.078
Psidium guajava	0.99	0.29	10.0	0.39	11.28	Myrtaceae	−0.065
Emblica officinalis	7.2	7.2	4.2	1.25	18.6	Euphorbiacae	−0.086
Albizzia procera	1.12	0.31	1.44	0.031	2.88	Mimosaceae	−0.065
Terminalia arjuna	1.4	5.3	5.0	2.0	11.7	Combretaceae	−0.93
Albizia chinensis	1.2	1.01	4.6	0.32	6.81	Fabaceae	−0.071
Gmelina aroba	2.24	1.46	2.89	0.073	6.6	Verbenaceae	−0.068

followed by *S. mahagoni* (17.1), *M. indica* (14.7), *Azadiracha indica* (14.4), *A. chinensis* (11.59), and *Emblica officinalis* (7.2). The most promising dominant species on the basis of IVI value were *A. heterophyllus* (56.57), *S. mahagoni* (46.2), *A. indica* (46.2), *M. indica* (41.1), and *A. chinensis* (39.11). However, *Syzygium cumini*, *Eucalyptus tereticornis*, *T. arjuna*, *A. chinensis*, *G. aroba*, and *Albizzia procera* with lower value may be considered as co-dominant species (Table 3). Basal area is also regarded as an index of dominant species, most basal area tree showed the most dominancy. By this reckoning, highly basal area was recorded for *M. indica* (3.86), *A. indica* (3.83), *S. mahagoni* (3.27), *S. robusta* (2.55), and *A. heterophyllus* (2.49).

Forest structure

The forests of the northern districts land are bestowed with tropical moist deciduous forests. This forest is intermingled with the neighboring settlements and fragmented into smaller patches (Dinajpur Forest Division 2007). The distribution of the total plot area across 1-ha plots, using GBH interval classes, reveal the dominance of small-stemmed individuals in the plot. The mean diameter of top 10 dominant tree species covers 62% of ground cover. It means minority of species dominate the majority of the available resources. Stem density and species richness have consistently decreased with increasing girth class of tree species from 10 to 155-cm girth. The highest numbers of

Table 4 Different species and individual's distribution according to Girth class intervals in three study sites

Girth class (cm)	Site 1		Site 2		Site 3		Total	Percent of total individuals
	Species	Individuals	Species	Individuals	Species	Individuals	Individuals	
<30	42	187	48	191	41	202	580	29.1
31–50	34	169	51	164	29	186	519	26
51–70	23	122	20	114	35	118	354	18
71–90	16	82	24	87	15	72	241	12.1
91–110	12	43	15	52	9	47	142	7.1
111–130	8	27	9	18	11	32	77	3.8
131–150	6	14	4	17	6	17	48	2.4
>151	5	11	3	8	3	11	30	1.5
	59	655	64	651	57	685	1,991	100

species were encountered in the low GBH class (10–50 cm). Species number gradually decreases with the fall of stems in higher girth class category (Table 4). Tree distribution by height intervals is shown in Fig. 2.

Most of the forest trees are economically valuable and indigenous species. The tree species belongs to height range of 15–<25 m and DBH range of 20–<30 cm and the less species belongs to height range of 10–<15 m and 60–<70 cm DBH range. The tallest individual tree was *S. robusta* (30 m) and *Swietenia macrophylla* (25 m) in site 1. In site 2, *S. robusta* (27 m) and *A. heterophyllus* (24 m) is the tallest tree. In Baliadangi beat (site 3), *D. sissoo* (25 m) and *M. indica* (22 m) was found as the tallest tree. Trees height in site 1 (35%) and site 2 (41%) show trends higher than the site 1 (45% of trees are less than 5 m). Tree heights are influenced by the abundance of saplings, richness of nutrients, and management practices. In natural regeneration, it is important to ensure that the species composition of the new crops is the most suitable for fulfilling the objectives of forest management (Champion and Seth 1968). Sustainable productive forest management also requires adequate control over a permanent forest area, supported by information on the composition of the main forest types, and on the silvicultural characteristics of the principal species, and of others which may compete with them at various stages of their growth and development (Mok 1992). Like many other tropical forests, this forest typically has both substantial seedlings and soil seed bank from which regeneration may occur. A similar study was carried out by Alam et al. (2008) in the sustainability of Sal forest in Tangail Division who observed that the average density was 45,982 seedlings per hectare. Haque and Alam (1988) also found 79,700 seedlings per hectare in Madhupur and Vawal gar block of Gazipur and Mymensingh division. The present study also supports the findings of Milde et al. (1985) who observed that natural regeneration in the undisturbed forest reserves of Bangladesh is quite plentiful and there is abundance of seed, seedlings, and young growing stock. But in the present study, tree species such as *S. robusta*, *M. indica*, *A. heterophyllus*, *D. sissoo*, *A. indica*, *Anthocephalus chinensis*, *C. fistula*, *S. mahagoni*, and *S. cumini* was found; but *S. cumini*, *S. mahagoni*, *Albizia procera*, and *C. fistula* was highly regenerated there.

Conclusion

From the study, it may be concluded that the forest of Thakurgaon is in a remnant condition due to the destruction done by the local people and lack of co-operation of forest department with the local people and is heterogeneous nature and composition. However, till now, this forest is extremely rich in plant diversity, even after disturbance occurrence by grazing, extraction of economical or medicinal species, and lack of management practice. Therefore, priority should be given to conserve these forests which are facing pressure from increasing population and their demand. Calculation of IVI helped in understanding the ecological significance of the species in tropical moist deciduous forest type. Species diversity and stem density is

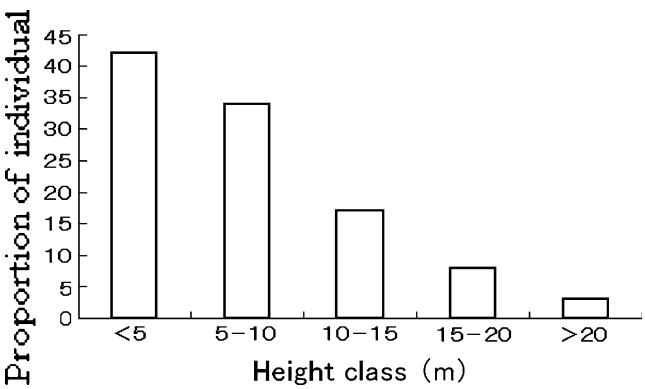

Fig. 2 Height class-wise proportion of individuals in the study sites

decreasing with the increasing of girth class. In order to maintain the complexity of this forest and its species diversity, an economically and ecologically sound management plan is desirable with minimum disturbance to the forest ecosystem. Long-term research on the forest and forest management practices must be given priority for the protection, conservation, and perpetuation of this forest region. The immediate attention on people's participation is most essential for effective conservation. The present study result will help as a primary input towards monitoring and sustaining the diversity of tropical moist deciduous forest of Bangladesh.

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