

## Tree species diversity and structural composition: The case of Durgapur Hill Forest, Netrokona, Bangladesh

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**Abstract.** Rahman MdR, Rahman MdM, Chowdhury MdA, Akhter J. 2019. Tree species diversity and structural composition: The case of Durgapur Hill Forest, Netrokona, Bangladesh. *Asian J For* 3: 10-19. Hill forest in Durgapur, Netrokona District, Bangladesh has been rarely studied to reveal its biodiversity information. This study aimed to assess tree species diversity and structural composition based on diameter and height class distribution in Durgapur hill forest (DHF). Tree inventory using stratified random sampling method was conducted during the period of October 2017 to May 2018 by establishing 42 sample plots with each plot had 20 m x 20 m in size. A total of 1436 stems of  $\geq 5$  cm DBH of 56 tree species belonging to 50 genera and 29 families were enumerated from the sampled area. Stem density was 855 stem ha<sup>-1</sup> and basal area was 29.27 m<sup>2</sup> ha<sup>-1</sup>. The Shannon-Wiener's, Margalef's, Simpson's and Pielou's diversity indices indicate that Durgapur hill forest had a moderately diverse tree species and lower diversity in comparison to other natural forests of the country. The study showed that the most dominant 10 species have 58% of the total IVI (174.29 out of 300) in which *Acacia auriculiformis* showed the maximum Importance Value Index (51.02) followed by *Shorea robusta* (24.23). Number of individual tree species was the highest (49) in the height range of 7- <12 m whereas maximum (52) species were recorded in the DBH (cm) range of 5- <10 cm. *Acacia auriculiformis*, *Shorea robusta*, and *Tectona grandis* were found as the most dominant species based on hierarchical cluster analysis. The current study will be helpful for policymakers in formulating forest resource management plan for Durgapur hill forest.

**Keywords:** Diversity indices, Durgapur hill forest, importance value index, phytosociological characters, structural composition

**Abbreviations:** DBH: Diameter at Breast Height, BBS: Bangladesh Bureau of Statistics, DHF: Durgapur hill forest, IFESCU: Institute of Forestry and Environmental Sciences, University of Chittagong, BFRI: Bangladesh Forest Research Institute, BA: Basal Area, D: Density, RD: Relative Density, F: Frequency, RF: Relative Frequency, A: Abundance, RA: Relative Abundance, Rdo: Relative Dominance, IVI: Importance Value Index, PSP: Permanent Sample Plot, ANR: Assist Natural Regeneration.

### INTRODUCTION

The diversity of plant species and structural composition plays a significant role in maintaining the integrity of forest ecosystems (Sajib et al. 2016; Rahman et al. 2017). Tree species diversity can serve as a proxy or indicator of the general pattern of the broader biological diversity of a forest. For example, a higher number of tree species is associated with a higher number of understory plants, or even animal diversity. Therefore, information on floristic composition, quantitative structure and diversity of tree vegetation is vital for understanding the functioning and dynamics of forest ecosystems (Reddy et al. 2008; Hossain et al. 2015). Such information is essential for sustainable use and management activities of a forest.

Bangladesh is situated in a transition between India and Myanmar (often so-called Indo-Myanmar) region. Because of the unique geophysical characteristics, the country has rich biological diversity containing about 5700 species of angiosperms (Nur et al. 2016). However, the depletion of native species was accelerating at an alarming rate due to the rapid deforestation and forest degradation (Hossain

2001). During the last few decades, some areas of natural forest in Bangladesh have been degraded due to anthropogenic activities, primarily by land encroachment (Rahman et al. 2017).

Undisturbed natural hill forests of Bangladesh are generally uneven-aged and multi-storied (Alam 2008). One of biologically important regions in Bangladesh is Durgapur hill forest located in Netrokona District. The district shares border with Garo Hills of India to the north and the biggest haor (swampy land) area of Sunamganj District to the east. A large variety of plants, including trees, grow in the district. As Durgapur hill forest of Netrokona is close to inland sal forest of Tangail-Mymensingh District, the species composition is almost similar in between the two districts whereas some of which are important for timber, such as sal (*Shorea robusta*), bot (*Ficus benghalensis*), tentul (*Tamarindus indica*), sada karo (*Albizia procera*), simul (*Bombax ceiba*) and aswatha (*Ficus religiosa*) (BBS 2013).

In government managed forests of Bangladesh, many researchers have investigated plant species diversity and forest stand structure (Nath et al. 1998; Nath et al. 2000;

Motaleb and Hossain 2011; Hossain et al. 2013; Feeroz and Uddin 2015; Hossain et al. 2015; Chowdhury et al. 2018a, b; Das et al. 2018). Recently, a taxonomic study was done by Rahman et al. (2017) concentrating on the flora of Madhupur National Park under different genera and families. Also, a clear understanding of forest stands parameters, i.e., diameter and height class distribution, and forest stocking are important for management strategies (Hossain et al. 2017). However, such scientific efforts are lacking in Durgapur Hill Forest (DHF), especially to reveal information regarding structural composition, plant diversity and conservation issues. Hence, the present study is conducted in DHF of Bangladesh aiming to assess tree species diversity and structural composition based on diameter and height class distribution. The results of this study will serve as baseline information to monitor changes in species composition and to undertake conservation and management activity of the hill forest in the future.

## MATERIALS AND METHODS

### Study area

The study area is located in the most northern part of Durgapur at the coordinates of 25°7'30" N and 90°41'18" E (Figure 1). Durgapur Upazila is a small city of Netrokona District, with an area of 293.42 km and consists of 7 unions. Durgapur is bordered by Meghalaya State of India to the north, Purbadhala and Netrokona Sadar to the south, Kalmakanda to the east, and Dhobaura sub-district to the west. There are three main rivers in Durgapur namely Old

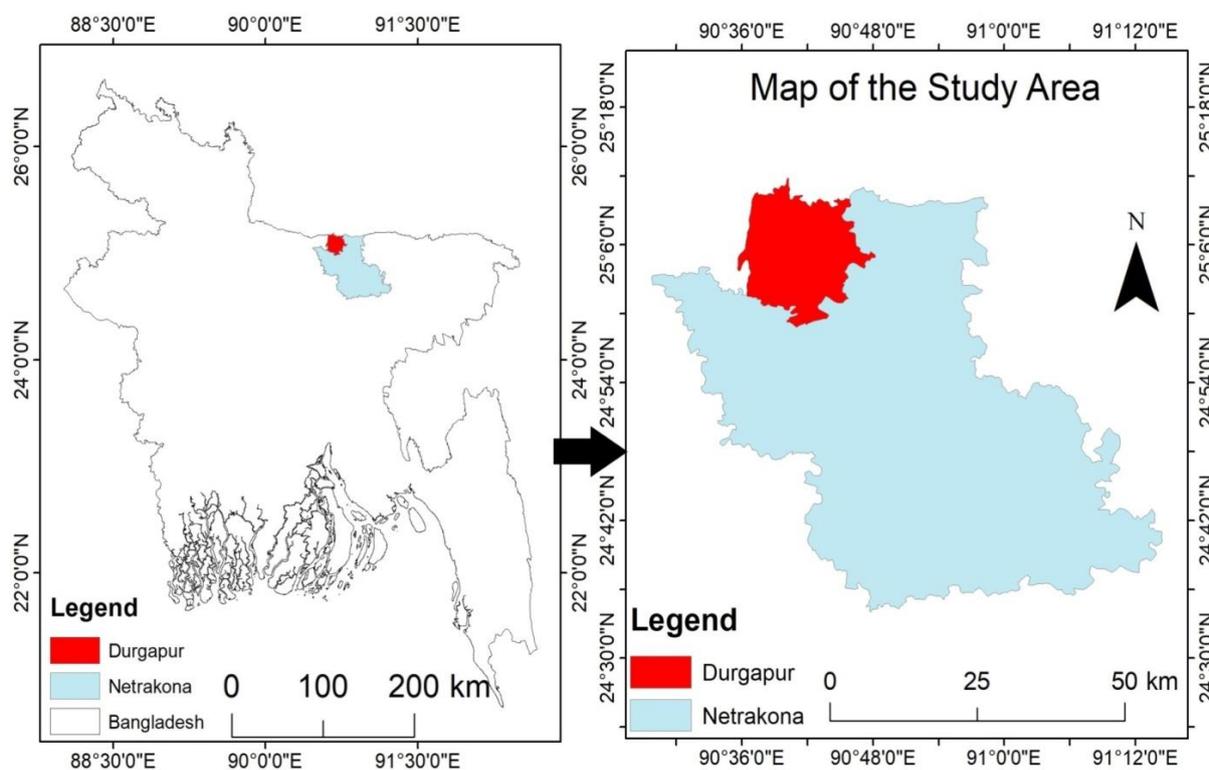
Someshwari, Kangsa and Someshwari.

Topographically, the study area is characterized by its large hillocks, known as 'tilla' with irregular plain land. This area is located in the semi-drier part of Bangladesh. The highest temperature reaches 30°C during May and the coldest to around 10°C during January. The area has an average rainfall 2712 mm per year.

### Data collection

Reconnaissance survey was conducted for planning of data collection with considerations of the accessibility of the forest, vegetation density and stratification, human settlement within the forest and fragmentation of the forest patches. Three transect walks across the study area were done.

The data collection was conducted from October 2017 to May 2018 to cover the whole study area. Stratified random sampling method was used for the inventory of the tree species. Sample plot with size of 20m × 20m was determined by applying the species-area curve of Caratti (2006) where a total of 42 sample plots were taken purposively. Sample plots were determined based on the area of the respected forest. Plots were taken both in natural and plantation forest patches having low, medium and dense tree cover. Position of each sample plot was then recorded using Ground Positioning System (GPS) device. Area of each plot was demarcated by measuring tape and rope. Plants having dbh ≥ 5 cm were recorded from the quadrats. Total height and diameter at breast height (dbh) of all trees inside the demarcated plots were measured using Suunto Clinometer and diameter tape respectively.



**Figure 1.** Map of the study area in Durgapur Upazila, Netrokona District, Bangladesh

For multi-stemmed trees, the bole dbh was measured below the forking (if height is 1.3 m from the ground) with each stem was considered as individual tree. Standard scientific method of dbh measurement was followed in other critical situations, i.e., buttressed stem, leaned tree, slope, etc.

Common tree species were identified directly in the field, while the samples of the unknown tree species were collected for the preparation of herbarium specimens and later those specimens were dried in the sun following standard scientific method. Consultation was done with published journals and reference books like Siddiqui et al. (2007) and Encyclopedia of Flora and Fauna of Bangladesh (Ahmed et al. 2008). Taxonomists from the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU) and the Bangladesh Forest Research Institute (BFRI) also helped with species identification. Besides, the author's own collections, the herbarium specimens previously collected from Madhupur National Park, Tangail were also examined (Rahman et al. 2017).

#### Analysis of field data

The field data were compiled and analyzed to determine the density, relative density (RD %), frequency, relative

frequency (RF %), abundance, relative abundance (RA %) and Importance Value Index (IVI). The equations used for calculating phytosociological characters are listed in Table 1 (Eq. No. 1-9). Besides, biodiversity indices such as Shannon's index, Simpson's diversity index, species evenness index, Margalef's index, etc., for the DHF were calculated and compared the findings with other studies in government managed forests of the country. The equations (Eq. No. 1-4) used for calculating biodiversity indices are listed in Table 2. Besides, hierarchical cluster analysis was done using computer software package SPSS.

Margalef's index (R) is high in communities that include a greater number of species and in which the number of individuals of each species decreases relatively slowly on passing from more abundant to less abundant ones (Margalef 1958). Shannon-Wiener diversity index value is maximum when the number of individuals of all species is equal; value is zero if there are only one species (Shannon-Wiener 1963). With Simpson's diversity index (D), 0 represents infinite diversity and 1, no diversity. Species Evenness index (E) also known as Shannon's equitable index, assumes a value between 0 and 1 with 1 being complete evenness (Pielou 1966).

**Table 1.** The list of equations used for calculating phytosociological characters of the vegetation

Phytosociological attributes	Formula	References
Basal area/ha (BA)	$BA = \frac{\sum \Pi X D^2 / 4}{\sum \text{Area of all quadrat}} \times 10000$	Shukla and Chandel (2000), Chowdhury et al. (2018b)
Density (D)	$D = \frac{a}{b}$	Shukla and Chandel (2000)
Relative density (RD)	$RD = \frac{n}{N} \times 100$	Misra (1968), Dallmeier et al. (1992)
Frequency (F)	$F = \frac{c}{b}$	Shukla and Chandel (2000)
Relative frequency (RF)	$RF = \frac{Fi}{\sum_{i=1}^n (Fi)}$	Misra (1968), Dallmeier et al. (1992)
Abundance (A)	$A = \frac{n}{c}$	Shukla and Chandel (2000)
Relative abundance (RA)	$RA = \frac{Ai}{\sum_{i=1}^n (Ai)}$	Shukla and Chandel (2000)
Relative dominance (D)	$RD = \frac{\text{Basal area of one species}}{\text{Total basal area}} \times 100$	Hossain et al. (2013), Chowdhury et al. (2018b)
Importance Value Index (IVI)	$IVI = RD + RF + RA$	Dallmeier et al. (1992), Shukla and Chandel (2000)

Note: D= dbh, a= Total no. of individuals of a species in all the quadrats, b= Total no. of quadrats studied, n= Total No. of individuals of the species, N= Total No. of individuals of all the species, c= Total no. of quadrats in which the species occurs, b= Total no. of quadrats studied, Fi = Frequency of one species, Ai= Abundance of one species

**Table 2.** The list of equations used for calculating biodiversity indices of the vegetation

Biodiversity indices	Formula	References
Shannon-Wiener's diversity index (H)	$H = -\sum_{i=1}^n P_i \ln P_i$	Shannon and Wiener (1963)
Margalef's species richness index (R)	$R = \frac{(S-1)}{\ln(N)}$	Margalef (1958)
Simpson's diversity index (D)	$D = \sum_{i=1}^n P_i^2$	Simpson (1949)
Species (Pielou's) evenness index (E)	$E = \frac{H}{\ln(S)}$	Pielou (1966)

Note: H = Shannon-Wiener's diversity index, N = Total no. of individuals of all the species, Pi = Number of individuals of i<sup>th</sup> species/Total number of individuals, S = Total number of species

**RESULTS AND DISCUSSION**

**Results**

*Tree species composition*

Tree is a vital element of any forest. A total of 56 species belongs to 50 genera and 29 families were recorded from the forest area. Mimosaceae was the most dominant family with 7 species and 4 genera followed by Arecaceae (4 species and 4 genera), Euphorbiaceae with 4 species and 4 genera and Combretaceae, Meliaceae, Myrtaceae, Moraceae, Rutaceae, Sapotaceae with 3 species each (Table 3).

*Diversity indices*

A total of 1436 individual stems were recorded from the Durgapur hill forest. The vacant area of the forest was covered with more or less mixed and mono plantations. Therefore, high stem density (855 stem ha<sup>-1</sup>) was also found there. The Shannon-Wiener's index (3.18), species evenness index (0.79) Margalef's diversity index (7.57), and The Simpson's diversity index (0.07) was calculated for the study area (Table 4). The values of Shannon-Wiener and Margalef's diversity index indicate proficient presence of plant species in the area. Lower value of Simpson's index also stands for moderately diverse tree species.

*Phytosociological characters of the tree species*

Basal area, density, relative density, relative frequency, relative abundance, relative dominance and Importance Value Index (IVI) of the recorded tree species are shown in (Table 5). Fifteen dominant tree species accounted for 73.53% of the individuals (1056 out of 1436), 79.27% of the basal area, 73.53% of the relative density, 59.39% of the relative frequency, 54.05 % of the relative abundance, 79.26 % of the relative dominance and 68.53% of the IVI. Highest IVI was found for *Acacia auriculiformis* (51.02) followed by *Shorea robusta* (24.23), *Tectona grandis* (22.86).

**Table 3.** List of tree species found in the DHF with family name

Scientific name	Local name	Family
<i>Acacia auriculiformis</i> A. Cunn. ex Benth. & Hook	Akashmoni	Mimosaceae
<i>Acacia mangium</i> Willd.	Mangium	Mimosaceae
<i>Aegle marmelos</i> (L.) Corr.	Bel	Rutaceae
<i>Albizia lebeck</i> (L.) Benth. & Hook	Kala Koro	Mimosaceae
<i>Albizia procera</i> (Roxb.) Benth.	Shilkoro	Mimosaceae
<i>Albizia richardiana</i> (Voigt.) King & Prain	Raj koro	Mimosaceae
<i>Alstonia scholaris</i> (L.) R. Br.	Chatian	Apocynaceae
<i>Aphanamixis polystachya</i> (Wall.) R.N. Parker.	Pitraj	Mimosaceae
<i>Aporosa</i> sp.	Kharjon	Euphorbiaceae
<i>Aquilaria agallocha</i> Roxb.	Agar	Thymeliaceae
<i>Araucaria cunninghamii</i> Sw.	Christmas tree	Araucariaceae
<i>Areca catechu</i> L.	Supari	Arecaceae
<i>Artocarpus heterophyllus</i> Lamk.	Kanthal	Moraceae

<i>Artocarpus lacucha</i> Buch.-Ham.	Borta	Moraceae
<i>Averrhoa carambola</i> L.	Kamranga	Oxalidaceae
<i>Azadirachta indica</i> A. Juss.	Neem	Meliaceae
<i>Barringtonia acutangula</i> (L.) Gaertn.	Hijal	Lecythidaceae
<i>Bischofia javanica</i> Blume	Kanjalbhadhi	Euphorbiaceae
<i>Bombax ceiba</i> L.	Shimul	Bombacaceae
<i>Borassus flabellifer</i> L.	Tal	Arecaceae
<i>Cassia fistula</i> L.	Sonalu	Caesalpinaceae
<i>Chukrasia tabularis</i> A. Juss.	Chickrassi	Meliaceae
<i>Cryptocarya amygdalina</i> Nees.	Ojha	Lauraceae
<i>Dillenia scabrella</i> Roxb. ex Wall.	Ajuli, Ajugi	Dilleniaceae
<i>Diospyros blancoi</i> A. DC.	Bilati gab	Ebenaceae
<i>Elaeis guineensis</i> Jacq.	Oil pulm	Arecaceae
<i>Eucalyptus camaldulensis</i> Dehnh	Eucalyptus	Myrtaceae
<i>Ficus hispida</i> L. f.	Dumor	Moraceae
<i>Gmelina arborea</i> Roxb.	Gamar, Jogi	Verbenaceae
<i>Grewia nervosa</i> (Lour.) Panigr.	Datoi	Tiliaceae
<i>Haldina cordifolia</i> (Roxb.) Ridsdale	Kaika, haldu	Rubiaceae
<i>Lagerstroemia speciosa</i> (L.) Pers.	Jarul	Lythraceae
<i>Limonia acidissima</i> L.	Kodbel	Rutaceae
<i>Litchi chinensis</i> Sonn.	Litchi	Sapindaceae
<i>Madhuca longifolia</i> (Koenig) MacBride	Mahua	Sapotaceae
<i>Mallotus philippensis</i> (Lamk.) Muell.-Arg.	Sinduri	Euphorbiaceae
<i>Mangifera indica</i> L.	Aam	Anacardiaceae
<i>Manilkara zapota</i> (L.) P. van Royen	Sofeda	Sapotaceae
<i>Mimusops elengi</i> L.	Bakul	Sapotaceae
<i>Moringa oleifera</i> Lamk.	Sajna	Moringaceae
<i>Murraya paniculata</i> (L.) Jack	Kamini	Rutaceae
<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Kadom	Rubiaceae
<i>Phoenix sylvestris</i> Roxb.	Khejur	Arecaceae
<i>Phyllanthus emblica</i> L.	Amloki	Euphorbiaceae
<i>Psidium guajava</i> L.	Payara	Myrtaceae
<i>Pterospermum acerifolium</i> (L.) Willd.	Moos	Sterculiaceae
<i>Samanea saman</i> (Jacq.) Merr.	Raintree	Mimosaceae
<i>Shorea robusta</i> Roxb. ex Gaertn.f.	Sal	Dipterocarpaceae
<i>Swietenia mahagoni</i> Jacq.	Mahagoni	Meliaceae
<i>Syzygium cumini</i> (L.) Skeels	Kalojam	Myrtaceae
<i>Tamarindus indica</i> L.	Tentul	Caesalpinaceae
<i>Tectona grandis</i> L. f.	Shegun	Verbenaceae
<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	Arjun	Combretaceae
<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Bohera	Combretaceae
<i>Terminalia chebula</i> Retz.	Haritaki	Combretaceae
<i>Ziziphus mauritiana</i> Lamk.	Boroi	Rhamnaceae

**Table 4.** Density and tree diversity indices of the DHF

Parameters	Values for DHF
Density ( stem ha <sup>-1</sup> )	855
Shannon-Wiener diversity index	3.18
Species evenness index	0.79
Margalef's diversity index	7.57
Simpson's diversity index	0.07

**Table 5.** Basal area, number of stems, relative density, relative frequency, relative abundance relative dominance, and Importance Value Index (IVI) for DHF

Scientific name	BA (m <sup>2</sup> /ha)	Ind. stem no	RA (%)	RD (%)	RF (%)	RDo (%)	IVI
<i>Acacia auriculiformis</i>	7.19	289	7.18	20.13	6.26	24.64	51.02
<i>Acacia mangium</i>	1.01	49	1.85	3.41	4.11	3.46	10.99
<i>Aegle marmelos</i>	0.06	7	0.87	0.49	1.25	0.20	1.94
<i>Albizia lebbeck</i>	0.17	9	0.87	0.63	1.61	0.57	2.81
<i>Albizia procera</i>	0.58	33	0.96	2.30	5.37	1.99	9.65
<i>Albizia richardiana</i>	0.57	23	2.86	1.60	1.25	1.96	4.81
<i>Alstonia scholaris</i>	0.39	26	1.03	1.81	3.94	1.33	7.07
<i>Aphanamixis polystachya</i>	0.29	26	1.03	1.81	3.94	0.99	6.74
<i>Aporosa wallichii</i>	0.04	6	1.74	0.42	0.54	0.14	1.10
<i>Aquilaria agallocha</i>	0.70	65	3.77	4.53	2.68	2.39	9.60
<i>Araucaria cunninghamii</i>	0.02	1	0.87	0.07	0.18	0.06	0.31
<i>Areca catechu</i>	0.04	3	0.87	0.21	0.54	0.14	0.88
<i>Artocarpus heterophyllus</i>	0.40	27	0.98	1.88	4.29	1.36	7.53
<i>Artocarpus lacucha</i>	0.29	19	1.03	1.32	2.86	0.98	5.16
<i>Averrhoa carambola</i>	0.13	6	0.87	0.42	1.07	0.43	1.92
<i>Azadirachta indica</i>	0.37	28	1.62	1.95	2.68	1.27	5.91
<i>Barringtonia acutangula</i>	0.14	11	1.06	0.77	1.61	0.46	2.84
<i>Bischofia javanica</i>	0.25	16	0.99	1.11	2.50	0.85	4.47
<i>Bombax ceiba</i>	0.46	22	1.13	1.53	3.04	1.59	6.16
<i>Borassus flabellifer</i>	0.08	10	2.90	0.70	0.54	0.26	1.49
<i>Cassia fistula</i>	0.61	22	1.59	1.53	2.15	2.10	5.78
<i>Chukrasia tabularis</i>	0.61	46	1.91	3.20	3.76	2.10	9.06
<i>Cryptocarya amygdalina</i>	0.04	3	0.87	0.21	0.54	0.12	0.86
<i>Dillenia pentagyna</i>	0.05	3	0.87	0.21	0.54	0.17	0.91
<i>Diospyros blancoi</i>	0.01	1	0.87	0.07	0.18	0.02	0.27
<i>Elaeis guineensis</i>	0.16	4	1.16	0.28	0.54	0.55	1.36
<i>Eucalyptus camaldulensis</i>	2.81	97	2.56	6.76	5.90	9.61	22.27
<i>Ficus hispida</i>	0.29	25	1.81	1.74	2.15	0.99	4.88
<i>Gmelina arborea</i>	0.49	29	2.10	2.02	2.15	1.66	5.83
<i>Grewia nervosa</i>	0.35	31	3.85	2.16	1.25	1.18	4.59
<i>Haldina cordifolia</i>	0.42	25	1.81	1.74	2.15	1.44	5.33
<i>Lagerstroemia speciosa</i>	0.09	7	1.01	0.49	1.07	0.29	1.85
<i>Limonia acidissima</i>	0.08	4	3.48	0.28	0.18	0.26	0.71
<i>Litchi chinensis</i>	0.08	5	2.17	0.35	0.36	0.26	0.96
<i>Madhuca longifolia</i>	0.00	1	0.87	0.07	0.18	0.01	0.26
<i>Mallotus philippensis</i>	0.31	40	3.16	2.79	1.97	1.06	5.81
<i>Mangifera indica</i>	0.24	11	3.19	0.77	0.54	0.81	2.11
<i>Manilkara zapota</i>	0.03	1	0.87	0.07	0.18	0.09	0.34
<i>Mimusops elengi</i>	0.09	5	1.09	0.35	0.72	0.30	1.36
<i>Moringa oleifera</i>	0.06	5	0.87	0.35	0.89	0.21	1.45
<i>Murraya paniculata</i>	0.01	1	0.87	0.07	0.18	0.05	0.29
<i>Neolamarckia cadamba</i>	0.31	11	0.74	0.77	2.33	1.06	4.16
<i>Phoenix sylvestris</i>	0.01	1	0.87	0.07	0.18	0.04	0.29
<i>Phyllanthus emblica</i>	0.08	4	0.87	0.28	0.72	0.26	1.25
<i>Psidium guajava</i>	0.03	4	1.16	0.28	0.54	0.10	0.91
<i>Pterospermum acerifolium</i>	0.12	8	2.32	0.56	0.54	0.40	1.49
<i>Samanea saman</i>	1.01	18	1.96	1.25	1.43	3.45	6.14
<i>Shorea robusta</i>	2.51	173	7.52	12.05	3.58	8.61	24.23
<i>Swietenia mahagoni</i>	0.53	24	3.48	1.67	1.07	1.81	4.55
<i>Syzygium cumini</i>	0.01	1	0.87	0.07	0.18	0.03	0.28
<i>Tamarindus indica</i>	0.37	10	0.97	0.70	1.61	1.28	3.59
<i>Tectona grandis</i>	3.45	97	3.51	6.76	4.29	11.81	22.86
<i>Terminalia arjun</i>	0.01	1	0.87	0.07	0.18	0.02	0.27
<i>Terminalia bellirica</i>	0.19	12	1.16	0.84	1.61	0.66	3.10
<i>Terminalia chebula</i>	0.61	23	1.33	1.60	2.68	2.10	6.38
<i>Ziziphus mauritiana</i>	0.02	7	0.87	0.49	1.25	0.06	1.80
Total	29.27	1436	100.00	100.00	100.00	100.00	300.00

Note: BA= Basal Area, RD= Relative Density, RF= Relative Frequency, RA= Relative Abundance, RDo= Relative Dominance and IVI= Importance Value Index

### Structural composition based on height classes

The vertical profile of a forest provides a clear concept of forest stratification. In the study we assigned six height classes considering total height of the tree individuals of different species with interval of 6 m. The six height classes were, 2- <7 m, 7- <12 m, 12- <17 m, 17- <22 m, 22- <27 m, and 27- <32 m. The distribution of individuals among different height classes showed a positively skewed curve, indicating a relatively stable population structure and regeneration status. Patterns of height (m) class distribution shows general trends of population dynamics and recruitment process to the maximum species in DHF. It was found that both the number of species and number of individuals decreased regularly with the increasing of total height. Both the number of tree species and number of individuals (56 species; 1436 individuals) were highest in the height range of 7- <12 m and lowest (2 species) in height range of 27- <32 m (Figure 2).

### Vertical structure of some dominant tree species

Height classes of trees are shown in Figure 3 (A-D) and Figure 3 (E-J). Figure 3 (A-D) is the representative of exotic species and Figure 3 (E-J) is the representative of native species. The study reveals that exotic species possessed mainly in first four height classes, i.e. *Acacia auriculiformis*, *Acacia mangium*, *Tectona grandis* except for *Eucalyptus camaldulensis*. However, the maximum height class for exotic tree species was found 2- <27 m range.

In case of native species, *Shorea robusta*, *Bombax ceiba*, and *Aquilaria agallocha* were found in four height classes whereas *Cassia fistula*, *Azadirachta indica*, and *Chukrassia tabularis* was present in three height classes.

### Structural composition based on DBH classes

The distribution of individuals among different DBH (cm) classes shows a reverse J-shaped curve (Figure 4). It indicates progressive decrease of tree individuals in larger tree size classes. The number of species and tree individuals was found to decrease with increasing diameter with very little exception. Both the tree species and individuals were maximum (52 species, 534 individuals) in 5- <10 cm dbh range and minimum (2 species, 4 individuals) in 45- <50 cm dbh range (Figure 3). As the dbh increases, both the number of species and number of tree individuals decrease. It indicates incidence of illegal felling of mature and economically important trees in the area. The higher number of trees in lower size classes also indicates recent initiatives for conservation, protection, and improvement of the forest.

### Distribution of some dominant tree species in different diameter classes

Diameter classes of trees are shown in Figure 5 (A-D) and Figure 5 (E-J). Figure 5 (A-D) is representative of exotic species and Figure 5 (E-J) is the representative of native species. In case of native species, *Shorea robusta* and *Terminalia chebula*, *Cassia fistula*, *Alstonia scholaris* were found in maximum dbh class with the highest density

in the first and second class decreasing with increasing dbh class forming inverted J shape.

In case of exotic species, the diameter class distribution of *Acacia auriculiformis*, *Acacia mangium*, *Shorea robusta*, *Eucalyptus camaldulensis*, etc. showed a reverse shape J-curve with a sharp drop in the higher diameter classes. The sharp decline and very low representation in the higher diameter classes depict illegal felling in the DHF. The presence of some large trees and the prevalence of small to medium size individuals also represent that the forest is in a second development stage.

### Hierarchical cluster based on the dominant tree species in the Durgapur hill forest

The study revealed tree species of DHF are grouped into four hierarchical clusters (Figure 4). *Acacia auriculiformis* was the most dominant species followed by *Shorea robusta*, *Tectona grandis*, *Eucalyptus camaldulensis* and the member of first cluster. Then *Samanea saman*, *Cassia fistula*, *Haldina cordifolia*, *Gamlina arborea*, etc. were the second most dominant species and the member of second cluster. Other species under this research form rest of the clusters (Figure 4). However, it is obvious that the dominated tree are exotic species. This indicates that the area is gradually converted with plantation activities.

### Discussion

Floral inventory is a prerequisite for fundamental research in community ecology, and for modeling patterns of species diversity and understanding species distribution patterns (Das et al. 2018). The tree species composition of DHF (56 tree species, 50 genera, 29 families) is closer to that found in tropical forests, for example, 50 tree species in Rampahar Natural Forest Reserve (Chowdhury et al. 2018a), 52 tree species in Kaptai National Park (Rahman et al. 2016), 62 tree species in Tankawati natural forest (Motaleb and Hossain 2011). However, DHF possessed lower tree species in comparison to 107 tree species in Kamalachari natural forest, Rangamati and Bandarban borderline (Hossain et al. 2015), 153 tree species in Tropical Forest of Eastern Ghats, India (Reddy et al. 2011) and 93 tree species in Chunati Wildlife Sanctuary (Nath et al. 2016).

As plantation activities are increasing in study area, the stem density (855 stems ha<sup>-1</sup>) is higher than 709 stems ha<sup>-1</sup> in tropical forest of Eastern Ghats, India (Reddy et al. 2011). But the number is lower than a study by Haider et al. (2013) in natural forests of Moulvibazar in Sylhet Forest Division where they recorded 1,051 tree individuals per ha, belonging to 81 species, 59 genera and 33 families. The basal area (29.27 m<sup>2</sup> ha<sup>-1</sup>) of DHF is lower than that of 47.02-62.16 m<sup>2</sup> ha<sup>-1</sup> in Tankawati natural forest of Chittagong South Forest Division (Motaleb and Hossain 2011). Besides, it is higher than 16.88 m<sup>2</sup> ha<sup>-1</sup> revealed by Rahman et al. (2000) and 21.10 ± 2.62 m<sup>2</sup> ha<sup>-1</sup> found by Hossain et al. (2015). The moderate number of tree species with higher stem density but lower basal area indicates that the forest area is suffering from deforestation.

The IVI value indicates a complete picture of phytosociological character of a species in the community. The study showed that the most dominant 10 species have 58% of the total IVI (174.29 out of 300), where the dominant tree species were *Acacia auriculiformis*, *Shorea*

*robusta*, *Alstonia scholaris*, *Tectona grandis*, etc. However, Hossain et al. (2015) showed that the most dominant 10 species have 34.67% of the total IVI (104 out of 300) and the amount is less than present findings.

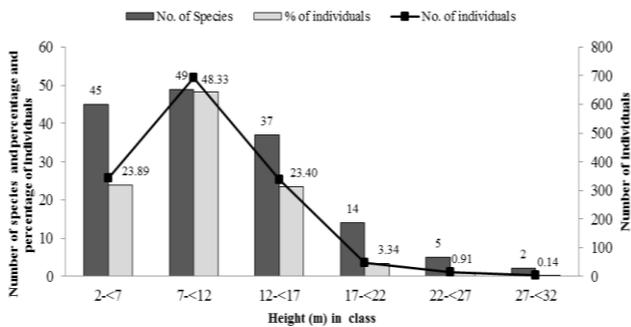


Figure 2. Distribution of tree species, % of tree individuals and individual number in different height (m) classes of DHF

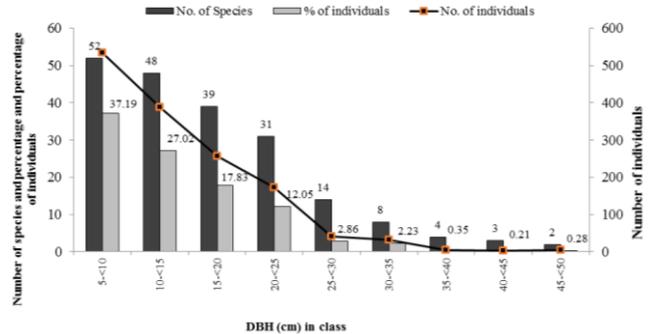


Figure 4. Distribution of tree species, % of tree individuals and individual number in different DBH (cm) classes of DHF

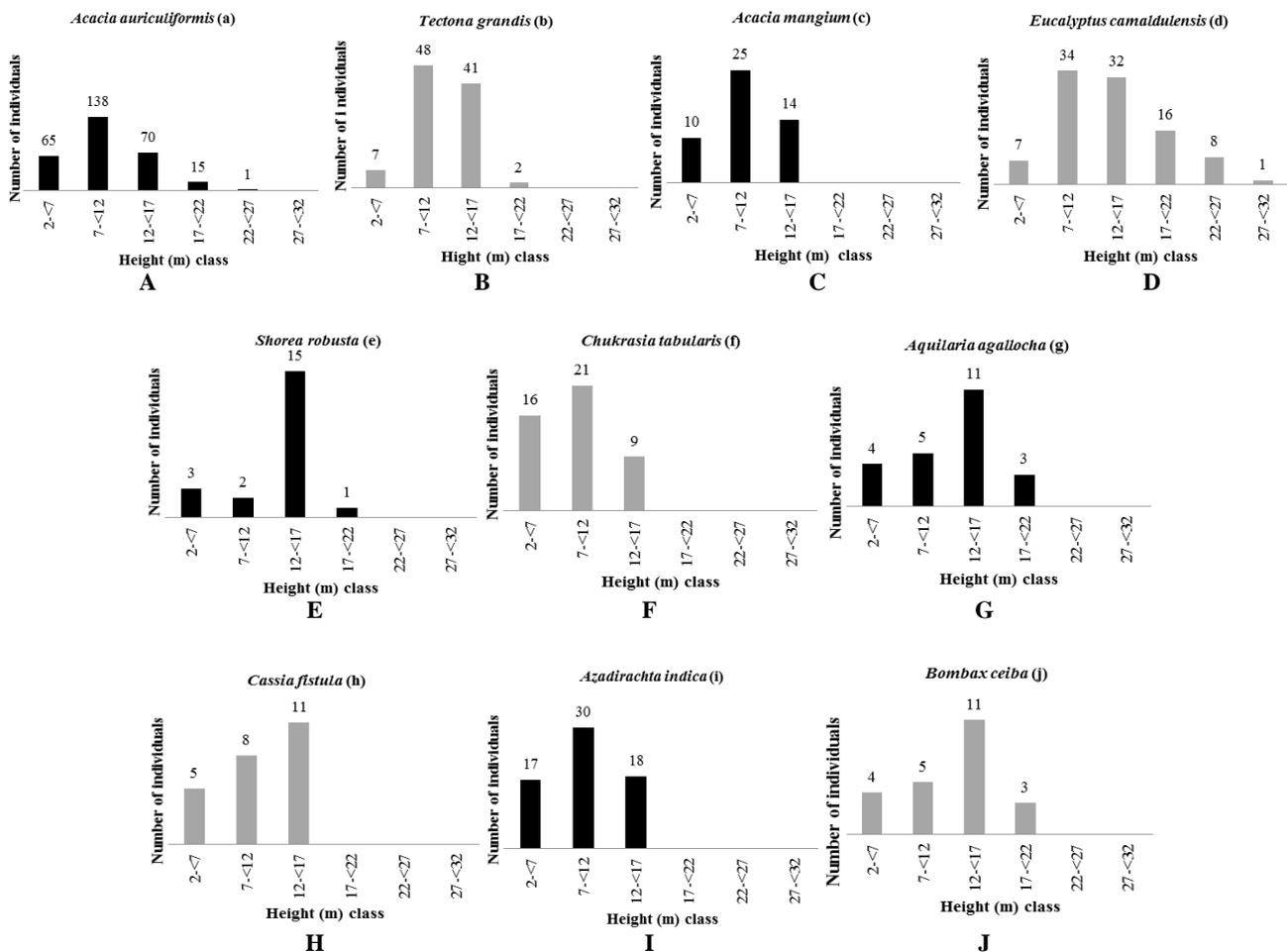
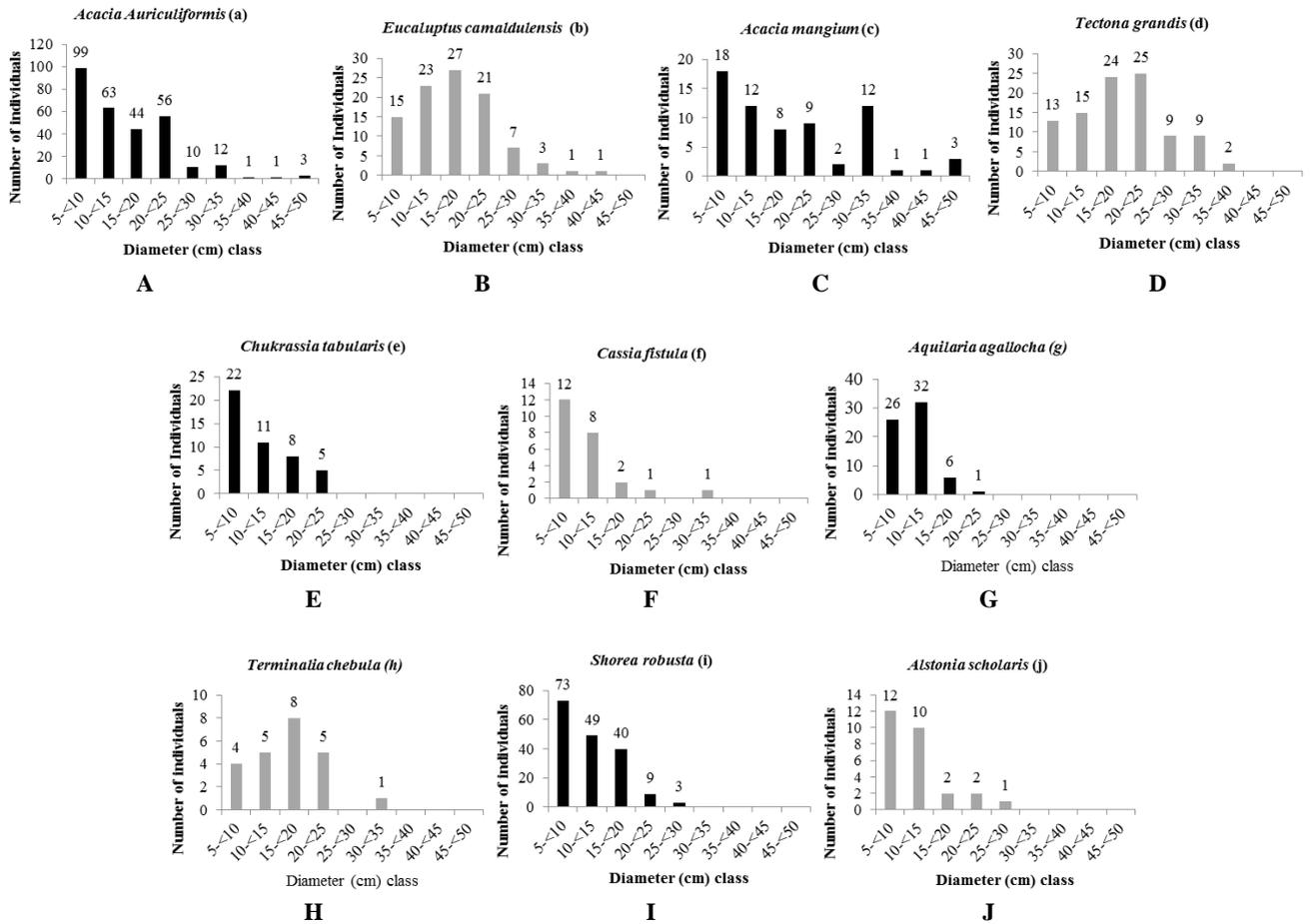
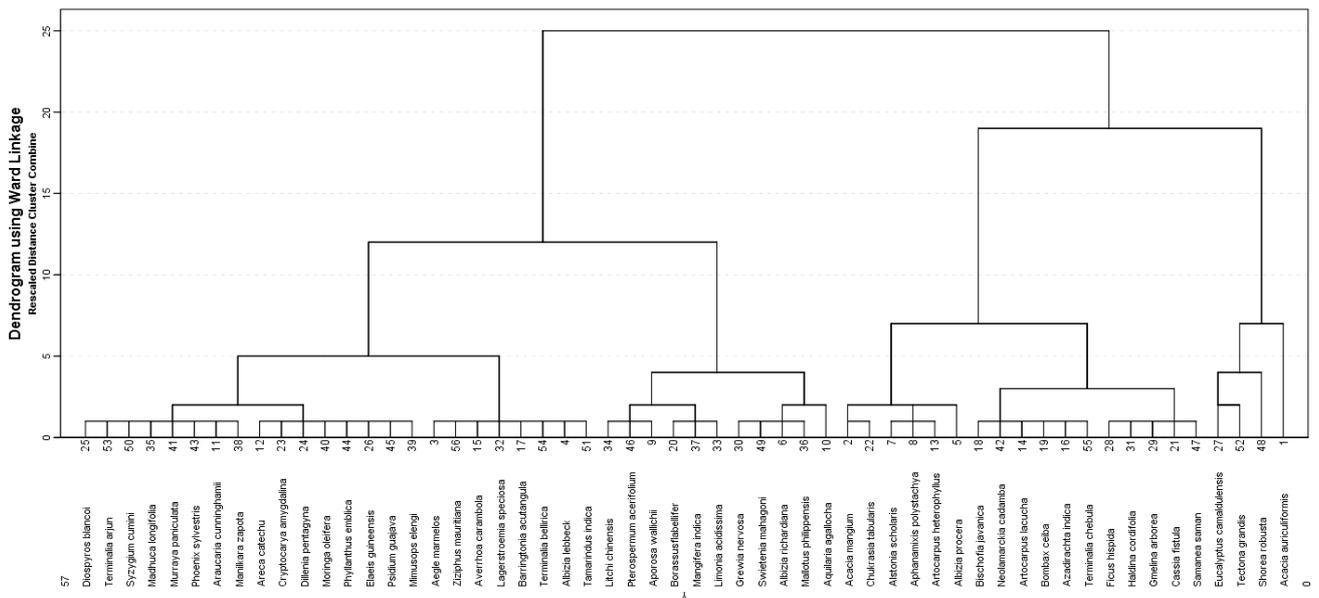


Figure 3. A-D. Height class distribution of some exotic tree species in DHF. E-J. Height class distribution of some native tree in DHF



**Figure 5.** A-D. Diameter (cm) class distribution of some exotic tree species in DHF. E-J. Diameter (cm) class distribution of some dominated tree species in DHF



**Figure 4.** Hierarchical cluster of the tree species in DHF

The maximum number of species (52) and percentage of tree individuals (37.19%) was found in the DBH range of 0.5–10 cm, whereas the maximum number of species (88) and percentage of tree individuals (66.02%) was found in the DBH range of 10.1–20 cm in Kamalachari natural forest of Chittagong south forest division (Hossain et al. 2015) and nearly 90% trees were belonging to 5- to 15-cm dbh class recorded from Chunati Wildlife Sanctuary (Nath et al. 2016). Besides, DBH range of 20.1–30 cm possessed both highest (58 species) number of species and percentage (29.69 %) of tree individuals in Tankawati Natural Forest Reserve of Chittagong (South) Forest Division, Bangladesh (Motaleb and Hossain 2009). Again, Hossain et al. (2015) revealed the number of tree species, tree individual percentage, and their number were highest (97 species, 77.99%, 404 individuals) in the height range of 4.5–14.4 m. Present study found that *Eucalyptus camaldulensis*, *Areca catechu*, *Averrhoa carambola*, *Elaeis guineensis*, *Tamarindus indica*, *Terminalia bellirica*, *Neolamarckia cadamba* dominated the upper canopy. The height class distribution indicates that Durgapur hill forest is a relatively well-stratified forest.

The Shannon-wiener diversity index of 3.18 is lower than that of 3.25 in Tankawati natural forest of Chittagong (South) Forest Division, 4.01 in Komolchori VCF of Khagrachari (Chowdhury et al. 2018) and 4.27 in Garo Hills of India (Kumar et al. 2006) where, but is very closely related with Chunati Wildlife Sanctuary (3.15) (Nath et al. 2016). Margalef's index (7.57), lower value of Simpson's index (0.07) and Species evenness index (0.79) indicate less species diversity in DHF in comparison to other natural forests of the country. However, it is alarming that the forest area is now dominated by some exotic species which should be rejuvenated with the native flora.

In conclusion, the study revealed that Durgapur hill forest had a moderately diverse tree species along with stratified tree populations. The IVI values revealed economically and ecologically most important tree species in the forest and those to be prioritized for conservation. The height class distribution indicates occurrences of illegal removal of trees from the forest. The dbh class distribution shows that some species are in poor regeneration status may be due to human disturbance and livestock grazing. Collection of sun-grass, intentional burning, and encroachment caused extensive loss of regenerated seedlings of important native tree species in the last decades. It is therefore recommended to establish some Permanent Sample Plots and Assisted Natural Regeneration plots, and adopt species-specific conservation measures to enhance regeneration status and tourism potentials of DHF. Special conservation measures both *ex-situ* and *in-situ* methods may be initiated to conserve the rare native plant species in this area. Improved law and policy, livelihoods and incentives and capacity building may be considered for the area adjacent people. Also, regular community patrolling should be done to stop the theft of valuable timber. Different encroachments like inhabitation, agricultural expansion, hunting, shooting, illegal cutting, fuelwood collection, etc. were seen in the forest during

field data collection. Therefore, such detrimental activities must be stopped immediately, otherwise, those will make the area more fragmented and reduce natural forest restoration capacity.

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