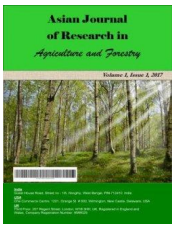

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The Riparian Tree Species Composition and Diversity of the Midstream of Halda River in Chittagong, Bangladesh

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Riparian vegetation has been depleting in the many river basins of Bangladesh. Consequently, this study assessed the tree species composition, structure and diversity of the midstream area of the Halda River in Bangladesh. Twenty two quadrats (20 × 20m in size) were sampled. A total of 414 individual tree stems of ≥10 cm DBH of 36 tree species belonging to 31 genera and 15 families were enumerated. Density, Basal area and volume of the tree species were measured. Different diversity indices, i.e. Shannon-Wienners Diversity Index, Simpson's Dominance Index, Pielou's Species Evenness Index, Margalef's and Menhinick's richness index were calculated. Fabaceae was the most represented family with nine species, followed by Moraceae, Meliaceae and Anacardiaceae. Density, basal area and volume of the trees were 470.45 stem/ha, 19.09m²/ha and 139.42m³/ha, respectively. *Samanea saman* was found to be dominant, showing a maximum IVI, followed by *v*, *Mangifer aindica*, *Eucalyptus camaldulensis* and *Artocarpus heterophyllus*. The findings of the study will be helpful for the posterior researchers in their research work and their future tree based planning programs and conservation. So it is recommended that greater emphasis should be taken to proper management and conservation against over extraction and illegal felling for the maintenance of existing tree species composition and density.

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Keywords: Bangladesh; diversity; Halda River; riparian tree species; species composition.

1. INTRODUCTION

Rivers are the prominent and important feature of the landscape, playing crucial roles in the development of any country. Any country's economy and development are greatly dependent on the ecosystem services that rivers provide such as fresh water supply, fish production, transportation, waste assimilation etc., along with the provision of a wide array of recreation and tourism options [1]. As a nationally important river the Halda River in Chittagong, Bangladesh needs to be conserved. This river hosts the breeding ground of major Indian carps from where the fertilized eggs are collected directly. Besides, Halda River is the main source of the drinking water for city of dwellers of Chittagong Metropolitan Area (CMA). However, this river is vulnerable due to many natural and anthropogenic factors. Different man made activities such as industrial discharge, tobacco farming discharge, rubber dam construction, brick-field construction, illegal quarrying for of sands etc. continue to threaten its existence [2]. Besides, the riverbank erosion, an increase of salinity in the river threatens the livelihood of several thousand fishermen and fish egg collectors. Some of these threatening and destructive factors can be maintained by a proper management of the riverbank tree species [3].

The riparian tree species play an important role in the reduction of river bank erosion which contributes to the maintenance of the river depth [4]. The tree cover and more tree species density is an important factor for an increasing rainfall which is important for dilution of the salinity and pollutants [5,6].

As Halda is one of the most resourceful rivers, many researches were conducted in the recent past. Studies were done to assess the surface water quality of Halda River from September 2015 to March 2016 [7], and the pollutants discharged into the Halda River through major canals [8]. The river flow of Haldaand its impact on Halda ecosystem was also estimated [9]. The conservation of Halda river in cooperation with river-dependent community was investigated in 2015(10). Studies were also done on the spawning of major Indian carp (11), while the biodiversity status of carps in the river assessed via their distribution and most important zones of spawning (12). Bhuyan and Bakar [2017] looked at the sediment and the heavy metal contamination in the water of the Halda River [7]. Zaman focused a research project on awakening local people who are dependent on this river [13].

Despite of all these studies above mentioned, the tree vegetation on the two banks of this river which is the most important component of Halda River ecosystem is still unexplored. Therefore, this investigation assessed the tree species composition and diversity of the midstream area of the river bank.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The Halda River is one of the major rivers in the South-East region of Bangladesh. Halda (22°28'56.09"N & 91°54'07.62"E), the third main river of Chittagong after the Karnaphuli and the Sangu, is such a resourceful river of Bangladesh which originates from the Batnatali Hill Ranges of Ramgarh Upazila under Khagrachari District, Bangladesh [14]. It flows through Fatikchhari, Hathazari and Raozan Upazila and Chandgaon Thana of Chittagong before ending into the Karnaphuli River. It is the only natural spawning ground of Indian major carp species [14]. The air temperature of the river was recorded 23℃ to 33℃throughout the year and monthly total rainfall ranged from 0.03 inches (December) to 31.75 inches (June) with '0' rainfall in January and February [15]. The research was carried out in the midstream of Halda River(from Nazirhat, Fatikchhari to Sattarghat, Raojan)which liesbetween22°30'49.608" to 22°37'40.152' north latitude &91°50'43.224" to 91°47'51.936" east longitudes (Fig. 1). The total length of the midstream area of this river from Nazirhat to Shattarghat is about 19.6km and about 8800 m^2 of the riparian midstream were sampled. The midstream area was covered with rural settlement, homestead forests, crop lands, fallow lands, water bodies, natural and plantation forests with exposed soil [16]. But in the riparian area homestead and plantation this two land class was mainly found.

2.2 Sampling Methods

Systematic sampling method was followed during inventory of tree species. The whole sampling and primary data collection was done by a small boat (cockleboat). The plots were taken with an

approximate interval of 2km by using GPS and after each of that 2 km (approx.) interval two sampling plots of 20 ×20 m in size were taken on the both sides of the river. Total 22 quadrants of 400 m^2 were taken on each sides of the river which covered about 8800 m^2 sampling area (Fig. 1). The plots were taken from the starting point of the tree species on each bank. Tree species having more than 10cm diameter at breast height (DBH) were counted and DBH of them were measured by diameter tape, then the total height and merchantable height were also measured by Relascope.

2.3 Data Analysis

After collection of field data, to calculate the diversity index, quantitative characteristics data were compiled and processed. Basal area of the tree species was calculated by the following equation [17]:

Basal area = $\pi D^2/4$; where, D = Diameter at breast height, π = 3.1416

For each species relative density, relative frequency, relative abundance and Importance Value Index (IVI) were calculated by the following methods [18]. Identified plants were arranged taxonomically and categorized according to their habit form.

I. Frequency and relative frequency (%):

Frequency of a species = $\frac{Totalno.of\ quadrate\ in\ which\ the\ species\ occurs}{Total\ number\ of\ quadrats\ studied}$

Relative Frequency (RF%) = $\frac{Frequency\ of\ one\ species}{sum\ of\ all\ frequencies} \times 100$

II. Density and relative density (%):

Density of a species = $\frac{Totalno.of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Totalno.of\ sample\ plots\ of\ all\ species}$

Relative density of a species = $\frac{Totalno.of\ individuals\ of\ the\ species}{Totalno.of\ individuals\ of\ all\ species} \times 100$

III. Abundance and relative abundance (%)

Abundance of a species = $\frac{Totalno.of\ individuals\ of\ a\ species\ in\ all\ the\ quadrats}{Totalno.of\ quadrats\ in\ which\ the\ species\ occured}$

Relative Abundance (RA%) = $\frac{Abundance\ of\ one\ species}{Total\ abundance\ of\ all\ the\ species} \times 100$

IV. Relative Dominance (%)

Relative Dominance (RDo) = $\frac{Basal\ area\ of\ a\ species\ in\ all\ quadrats}{Total\ basal\ area\ of\ all\ species\ in\ all\ quadrats} \times 100$

V. Important Value Index (IVI)

Importance Value Index (IVI) = Relative Frequency (RF) + Relative Density (RD) + Relative Dominance (RDo); according to Curtis, 1959 [19,20].

2.4 Functional Diversity

Functional diversity is defined as the variety of interactions with ecological process and can be quantified by determining the nature and extent to which functional groups are represented in an ecological system [21]. Functional diversity, evenness and richness were measured using different methods.

Generally, species diversity is determined not only by the number of species within a biological community, such as; species richness, but also by the relative abundance of individuals in that community. Species abundance is the number of individuals per species, and relative abundance refers to the evenness of distribution of individuals among species in a community. Two communities may be equally rich in species but differ in relative abundance [22].

Four diversity indices, such as; Shannon-Wienner Diversity Index (H), Margalef 's richness index (R), Simpon's Diversity Index (D), Pielou's Species Evenness Index (E) and Menhinick's richness index(DI) [23-26] were analysed to get a picture of tree species diversity in Halda river as following.

I. Shannon-Weinner Diversity Index

The Shannon-Weinner's biodiversity Index is commonly used to characterize species diversity in a tree species community. As like as Simpson's index, Shannon's index accounts for both abundance and evenness of the species present. Equitability assumes a value between 0 and 1 with 1 being complete evenness.

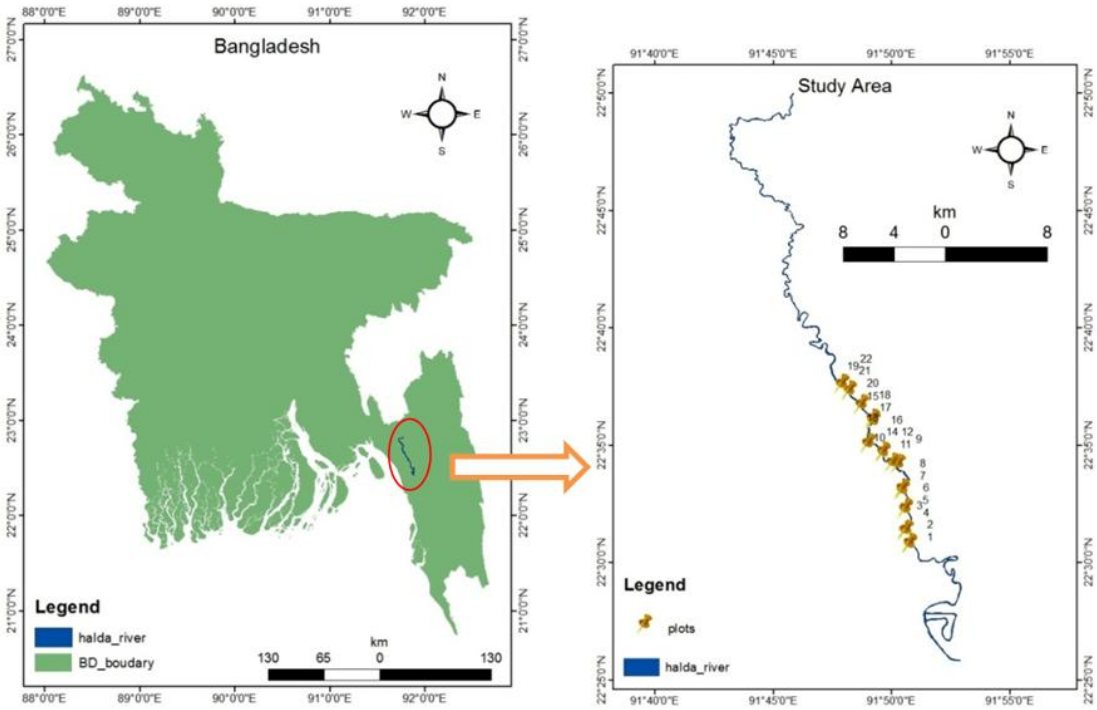

Fig. 1. Map of the study area of Halda River

Shannon-Wienner's diversity index value is Maximum when the number of individuals of all species is equal; value is zero if there is only one species [25].

Shanon-Weinners equation:

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

Where,

H = The Shannon diversity index
P_i = Fraction of the entire population made-up of species i
S = Numbers of species encountered
∑ = Sum from species 1 to species S

II. Simpson's Diversity Index

A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. It is a measurement of diversity which takes into account the number of species present as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

Simpson's Index, $D = \frac{\sum n\,(n-1)}{N(N-1)}$

n = Total number of organisms of a particular species
N = Total number of organisms of all species
D= Simpson's Diversity Index

With this index, 0 represents infinite diversity and 1 indicates no diversity. That is meant that the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 [24]

So, Simpson's Index of Diversity = 1 – D

The value of this index also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity.

III. Margalef's Richness index

It is measured by: R=S-1/ln N

Where,

R= Margalef's Richness index
S=Total no. of species
N=Total no. of individual of all species

Margalef's richness 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 the more abundant to the less abundant ones [23].

IV. Pielou's Species Evenness Index

It is measured by the following equation:

$$E = \frac{H}{Ln(S)}$$

Where,

E = Species Evenness
H = The Shanon-Weinner's biodiversity Index
S= Total number of species

V. Menhinick's richness index

Menhinick's richness index was calculated by using the formula given by Menhinick (1964) as:

$$DI = \frac{S}{\sqrt{N}}$$

Where,

DI= Menhinick's richness index
S=No. of species
N=No. of total species

2.5 Structural Composition

A total of 448 tree stems per ha were considered for height class distribution. The tree individuals were categorized into 4 height classes and a total of 414individuals having (DBH) ≥10cm were categorized into 7 diameter classes to determine the structural composition of the tree species.

3. RESULTS

3.1 Tree Species Composition

A complete list of trees having Diameter at Breast Height (DBH) ≥10cm were recorded from the total 22 quadrates of Halda riparian areas. A total of 36 tree species belonging to 31 genera and 15 families were recorded from the quadrates. The most common tree species were *Swietenia mahagoni, Samanea saman, Mangifera indica, Areca catechu, Artocarpus heterophyllus, Albizia lebbeck, Acacia auriculiformis* etc. (Tables 1 and 2). Fabaceae family shows the highest number of tree species [9] followed by Moraceae and Meliaceae [4] and Anacardiaceae, Arecaceae and Myrtaceae each with 3 tree species. Stem density per hectare was found to be 470.45 stem/ha in total, where *Swietenia mahagoni* possessed the highest followed by *Samanea saman* and *Eucalyptus camaldulensis* (Table 2). Total Basal area and volume of all the recorded tree species were calculated as 19.09m²/ha and 139.42m³/ha respectively. *Swietenia mahagoni* was noticed as highly dominant plant species. People also planted *Samanea saman, Eucalyptus camaldulensis, Mangifera indica, Artocarpus heterophyllus, Areca catechu, Albizia lebbeck, Acacia auriculiformis, Acacia mangium, Bombaxceiba* for meeting fruit, fuel, timber needs.

3.2 Diversity Indices

Among the diversity indices, 2.86 was found for Shannon-Wienners Diversity Index where Simpson's Dominance Index was 0.91. Moreover, Margalef's Richness Index was calculated as 5.81, Pielou's Species Evenness Index was 0.80 and Menhinick's richness index was 1.77 (Table 3).

3.3 Importance Value Index (IVI) of Riparian Halda Tree Species

Importance Value Index (IVI) of the tree species was assessed along with basal area (BA), Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo) of each species. *Samanea saman* possessed the highest IVI (59.28%) followed by 40.92% of *Swietenia mahagoni*, 24.12% by *Mangifera indica*, 18.12% by *Eucalyptus camaldulensis* and 17.69% by *Artocarpus heterophyllus* shown in (Table 4 and Fig. 2).

3.4 Structural Composition Based on Height (m) Classes

The structural composition of tree species of Riparian Halda tree species was assumed by determining 4 height classes, such as;2- <7 m, 7- <12 m, 12- <17 m, and 17- <22 m (Table 5). The highest percentage of tree individuals (47.34%) belong to the12- <17 m height class followed by 7- <12 m (34.54%) and 17- <22 m height class (9.90%). The lowest percent (8.21%) of trees occurred in highest height class 2- <7 m range. Number of tree species, % of the tree individuals and number of tree individuals showed that

maximum species occurred in height class of 12- <17 m.

3.5 Structural Composition of Tree Species Based on Diameter Class Distribution

7 diameter classes (cm) were determined to assume the structural composition. These were 10- <20 cm, 20 -<30 cm, 30- <40 cm, 40- <50 cm, 50- <60 cm, 60- <70 cm and 70- <80 cm. Among them, 48.79% of all the tree individuals (202 tree stems of 414 stems) belonging to 26 tree species were in the diameter range of 10- <20 cm (Table 6). Only *Samanea saman* belongs to the highest dbh class 70- <80 cm.

Table 1. List of tree species recorded from Halda riparian

Sl. No.	Family	Sl. No.	Binomial name	Local name	No. of individual
1	Anacardiaceae	1	*Mangifera indica*	Aam	33
		2	*Spondiasmombin*	Amra	1
		3	*Lannea coromandelica*	Jiol Badi	8
2	Apocynaceae	1	*Alstoniascholaris*	Chatim	1
3	Arecaceae	1	*Areca catechu*	Supari	21
		2	*Cocos nucifera*	Narikel	9
		3	*Borassus flabellifer*	Tal	1
4	Bombacaceae	1	*Bombax ceiba*	Shimul	13
5	Dipterocarpaceae	1	*Dipterocarpus turbinatus*	Teliya Garjan	1
6	Elaeocarpaceae.	1	*Elaeocarpus serratus*	Jalpai	1
7	Euphorbiaceae	1	*Trewianudiflora*	Pitali	9
8	Fabaceae	1	*Samanea saman*	Raintree	66
		2	*Acacia auriculiformis*	Akashmoni	15
		3	*Acacia mangium*	Mangium	14
		4	*Erythrina variegata*	Mandar	6
		5	*Albizia lebbeck*	Kalokoroi	16
		6	*Albizia procera*	Sadakoroi	6
		7	*Sennasiamea*	Minjiri	1
		8	*Albizia odoratissima*	Tetuakoroi	2
		9	*Cassia fistula*	Sonalu	1
9	Lythraceae	1	*Lagerstroemia speciosa*	Jarul	10
10	Meliaceae	1	*Swietenia mahagoni*	Mahagoni	74
		2	*Aphanamixis polystachya*	Pitraj	1
		3	*Khaya anthotheca*	Lombu	7
10	Meliaceae	4	*Chukrasia tabularis*	Chikrashi	4
11	Moraceae	1	*Artocarpus heterophyllus*	Kanthal	20
		2	*Ficus benghalensis*	Bot	2
		3	*Streblus asper*	Sheora	4
		4	*Artocarpus lacucha*	Borta	4
12	Myrtaceae	1	*Eucalyptus camaldulensis*	Eucalyptus	42
		2	*Syzygium grandae*	Dhakijam	1
		3	*Syzygium fruticosum*	Puti jam	5
13	Rhamnaceae	1	*Ziziphus jujuba*	Boroi	1
14	Rubiaceae	1	*Neolamarckia cadamba*	Kadam	7
15	Verbenaceae	1	*Gmelina arborea*	Gamar	5
		2	*Tectona grandis*	Shegun	2

Table 2. List of tree species with stem density per hectare recorded from Halda riparian area

Serial number	Local name	Binomial name	No. of individual	Stem/ha
1	Akashmoni	*Acacia auriculiformis*	15	17.05
2	Mangium	*Acacia mangium*	14	15.91
3	Kalokoroi	*Albizia lebbeck*	16	18.18
4	Tetuakoroi	*Albizia odoratissima*	2	2.27
5	Sadakoroi	*Albizia procera*	6	6.82
6	Chatim	*Alstonia scholaris*	1	1.14
7	Pitraj	*Aphanamixis polystachya*	1	1.14
8	Supari	*Areca catechu*	21	23.86
9	Kanthal	*Artocarpus heterophyllus*	20	22.73
10	Borta	*Artocarpus lacucha*	4	4.55
11	Shimul	*Bombax ceiba*	13	14.77
12	Tal	*Borassus flabellifer*	1	1.14
13	Sonalu	*Cassia fistula*	1	1.14
14	Chikrashi	*Chukrasia tabularis*	4	4.55
15	Narikel	*Cocos nucifera*	9	10.23
16	Teliyagarjan	*Dipterocarpus turbinatus*	1	1.14
17	Jalpai	*Elaeocarpus serratus*	1	1.14
18	Mandar	*Erythrinavariegata*	6	6.82
19	Eucalyptus	*Eucalyptus camaldulensis*	42	47.73
20	Bot	*Ficus benghalensis*	2	2.27
21	Gamar	*Gmelina arborea*	5	5.68
22	Lombu	*Khaya anthotheca*	7	7.95
23	Jarul	*Lagerstroemia speciosa*	10	11.36
24	Jiolbadi	*Lannea coromandelica*	8	9.09
25	Aam	*Mangifera indica*	33	37.50
26	Kadam	*Neolamar ckiacadamba*	7	7.95
27	Raintree	*Samanea saman*	66	75.00
28	Minjiri	*Senna siamea*	1	1.14
29	Amra	*Spondia smombin*	1	1.14
30	Sheora	*Streblus asper*	4	4.55
31	Mahagoni	*Swietenia mahagoni*	74	84.09
32	Puti jam	*Syzygium fruticosum*	5	5.68
33	Dhakijam	*Syzygium grandae*	1	1.14
34	Shegun	*Tectona grandis*	2	2.27
35	Pitali	*Trewia nudiflora*	9	10.23
36	Boroi	*Ziziphus jujuba*	1	1.14

Table 3. Diversity indices of the tree species in Halda riparian area

Diversity indices	Diversity index value
Shannon-Wienner Diversity Index	2.86
Simpon's Diversity Index	0.91
Margalef's Richness Index	5.81
Pielou's Species Evenness Index	0.80
Menhinick's richness index	1.77

Table 4. Phytosociological attributes of the recorded tree species from the 22 quadrats in riparian Halda

Sl. No.	Binomial name	Local name	BA (m)	RD (%)	RF (%)	RA (%)	RDo (%)	IVI
1	*Acacia auriculiformis*	Akashmoni	0.39	3.62	4.08	3.03	2.06	9.77
2	*Acacia mangium*	Mangium	0.50	3.38	3.40	3.40	2.60	9.38
3	*Albizia lebbeck*	Kalokoroi	0.94	3.86	2.04	6.47	4.90	10.81
4	*Albizia odoratissima*	Tetuakoroi	0.09	0.48	0.68	2.43	0.46	1.63
5	*Albizia procera*	Sadakoroi	0.28	1.45	2.04	2.43	1.47	4.96
6	*Alstonia scholaris*	Chatim	0.05	0.24	0.68	1.21	0.28	1.20
7	*Aphanamixis polystachya*	Pitraj	0.02	0.24	0.68	1.21	0.08	1.00
8	*Areca catechu*	Supari	0.23	5.07	2.72	6.37	1.20	9.00
9	*Artocarpus heterophyllus*	Kanthal	1.03	4.83	7.48	2.21	5.38	17.69
10	*Artocarpus lacucha*	Borta	0.17	0.97	2.72	1.21	0.90	4.59
11	*Bombax ceiba*	Shimul	1.34	3.14	6.12	1.75	7.01	16.28
12	*Borassus flabellifer*	Tal	0.05	0.24	0.68	1.21	0.25	1.17
13	*Cassia fistula*	Sonalu	0.03	0.24	0.68	1.21	0.13	1.06
14	*Chukrasia tabularis*	Chikrashi	0.16	0.97	2.04	1.62	0.83	3.83
15	*Cocos nucifera*	Narikel	0.42	2.17	2.72	2.73	2.18	7.07
16	*Dipterocarpus turbinatus*	Teliyagarjan	0.05	0.24	0.68	1.21	0.25	1.17
17	*Elaeocarpus serratus*	Jalpai	0.02	0.24	0.68	1.21	0.12	1.04
18	*Erythrina variegata*	Mandar	0.09	1.45	2.04	2.43	0.50	3.99
19	*Eucalyptus camaldulensis*	Eucalyptus	0.87	10.14	3.40	10.19	4.58	18.12
20	*Ficus benghalensis*	Bot	0.12	0.48	1.36	1.21	0.61	2.46
21	*Gmelina arborea*	Gamar	0.29	1.21	2.04	2.02	1.54	4.79
22	*Khaya anthotheca*	Lombu	0.13	1.69	0.68	8.50	0.66	3.03
23	*Lagerstroemia speciosa*	Jarul	0.39	2.42	3.40	2.43	2.03	7.84
24	*Lannea coromandelica*	Jiolbadi	0.19	1.93	3.40	1.94	0.99	6.33
25	*Mangifera indica*	Aam	1.91	7.97	6.12	4.45	10.03	24.12
26	*Neolamar ckiacadamba*	Kadam	0.38	1.69	2.72	2.12	1.98	6.39
27	*Samanea saman*	Raintree	5.80	15.94	12.93	4.22	30.41	59.28
28	*Senna siamea*	Minjiri	0.06	0.24	0.68	1.21	0.29	1.21
29	*Spondia smombin*	Amra	0.01	0.24	0.68	1.21	0.06	0.99
30	*Streblus asper*	Sheora	0.11	0.97	2.04	1.62	0.58	3.59
31	*Swietenia mahagoni*	Mahagoni	2.06	17.87	12.24	4.99	10.81	40.92
32	*Syzygium fruticosum*	Puti jam	0.13	1.21	2.04	2.02	0.70	3.95
33	*Syzygium grandae*	Dhakijam	0.10	0.24	0.68	1.21	0.53	1.46
34	*Tectona grandis*	Shegun	0.10	0.48	0.68	2.43	0.52	1.68
35	*Trewia nudiflora*	Pitali	0.58	2.17	2.04	3.64	3.02	7.24
36	*Ziziphus jujube*	Boroi	0.01	0.24	0.68	1.21	0.06	0.99

[Here, RD = Relative density, RF = Relative Frequency, RA = Relative Abundance, RDo = Relative Dominance, IVI = Importance Value Index]

Table 5. Percentage distribution of tree species in different height (m) classes

Binomial name	% distribution of tree species into different height(m) classes				Total
	2- <7 m	7- <12 m	12- <17 m	17- <22 m	
Acacia auriculiformis	0.00	1.45	2.17	0.00	3.62
Acacia mangium	0.48	1.21	1.69	0.00	3.38
Albizia lebbeck	0.00	0.24	0.97	2.66	3.86
Albizia odoratissima	0.00	0.48	0.00	0.00	0.48
Albizia procera	0.00	0.24	1.21	0.00	1.45
Alstonia scholaris	0.00	0.24	0.00	0.00	0.24
Aphanamixis polystachya	0.00	0.24	0.00	0.00	0.24
Areca catechu	0.00	0.48	4.59	0.00	5.07

Binomial name	% distribution of tree species into different height(m) classes				Total
	2- <7 m	7- <12 m	12- <17 m	17- <22 m	
Artocarpus heterophyllus	0.97	3.14	0.72	0.00	4.83
Artocarpus lacucha	0.00	0.24	0.72	0.00	0.97
Bombax ceiba	0.00	0.97	1.45	0.72	3.14
Borassus flabellifer	0.00	0.24	0.00	0.00	0.24
Cassia fistula	0.00	0.24	0.00	0.00	0.24
Chukrasia tabularis	0.00	0.00	0.97	0.00	0.97
Cocos nucifera	0.24	1.21	0.00	0.72	2.17
Dipterocarpus turbinatus	0.00	0.24	0.00	0.00	0.24
Elaeocarpus serratus	0.00	0.00	0.24	0.00	0.24
Erythrina variegata	1.21	0.24	0.00	0.00	1.45
Eucalyptus camaldulensis	0.24	0.00	5.56	4.35	10.14
Ficus benghalensis	0.24	0.24	0.00	0.00	0.48
Gmelina arborea	0.00	0.00	0.97	0.24	1.21
Khaya anthotheca	0.00	1.21	0.48	0.00	1.69
Lagerstroemia speciosa	0.00	1.69	0.72	0.00	2.42
Lannea coromandelica	1.93	0.00	0.00	0.00	1.93
Mangifera indica	1.69	1.45	4.83	0.00	7.97
Neolamar ckiacadamba	0.00	0.00	1.69	0.00	1.69
Samanea saman	0.72	3.86	11.35	0.00	15.94
Senna siamea	0.00	0.00	0.24	0.00	0.24
Spondias mombin	0.24	0.00	0.00	0.00	0.24
Streblus asper	0.00	0.97	0.00	0.00	0.97
Swietenia mahagoni	0.00	12.56	5.31	0.00	17.87
Syzygium fruticosum	0.00	1.21	0.00	0.00	1.21
Syzygium grandae	0.00	0.00	0.24	0.00	0.24
Tectona grandis	0.00	0.00	0.00	0.48	0.48
Trewia nudiflora	0.00	0.24	1.21	0.72	2.17
Ziziphus jujube	0.24	0.00	0.00	0.00	0.24
Total	8.21	34.54	47.34	9.90	100

Table 6. Percentage distribution of each tree species into different diameter (cm) classes

Binomial name	% distribution of tree individuals into different diameter(cm) classes							Total
	10-<20	20-<30	30-<40	40-<50	50-<60	60-<70	70-<80	
Acacia auriculiformis	2.66	0.97	0.00	0.00	0.00	0.00	0.00	3.62
Acacia mangium	1.69	1.69	0.00	0.00	0.00	0.00	0.00	3.38
Albizia lebbeck	0.24	2.66	0.97	0.00	0.00	0.00	0.00	3.86
Albizia odoratissima	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.48
Albizia procera	0.00	1.45	0.00	0.00	0.00	0.00	0.00	1.45
Alstonia scholaris	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Aphanamixis polystachya	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Areca catechu	5.07	0.00	0.00	0.00	0.00	0.00	0.00	5.07
Artocarpus heterophyllus	1.69	1.93	1.21	0.00	0.00	0.00	0.00	4.83
Artocarpus lacucha	0.24	0.72	0.00	0.00	0.00	0.00	0.00	0.97
Bombax ceiba	0.72	0.97	0.48	0.48	0.24	0.24	0.00	3.14
Borassus flabellifer	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Cassia fistula	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Chukrasia tabularis	0.24	0.72	0.00	0.00	0.00	0.00	0.00	0.97

Binomial name	% distribution of tree individuals into different diameter(cm) classes							Total
	10-<20	20-<30	30-<40	40-<50	50-<60	60-<70	70-<80	
Cocos nucifera	0.72	1.45	0.00	0.00	0.00	0.00	0.00	2.17
Dipterocarpus turbinatus	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Elaeocarpus serratus	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Erythrina variegata	1.45	0.00	0.00	0.00	0.00	0.00	0.00	1.45
Eucalyptus camaldulensis	7.97	2.17	0.00	0.00	0.00	0.00	0.00	10.14
Ficu sbenghalensis	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.48
Gmelinaar borea	0.00	0.24	0.97	0.00	0.00	0.00	0.00	1.21
Khaya anthotheca	1.69	0.00	0.00	0.00	0.00	0.00	0.00	1.69
Lagerstroemia speciosa	0.72	1.45	0.24	0.00	0.00	0.00	0.00	2.42
Lannea coromandelica	1.69	0.24	0.00	0.00	0.00	0.00	0.00	1.93
Mangifera indica	3.14	2.42	1.69	0.72	0.00	0.00	0.00	7.97
Neolamarckia cadamba	0.00	1.69	0.00	0.00	0.00	0.00	0.00	1.69
Samanea saman	3.14	6.04	4.35	1.21	0.24	0.24	0.72	15.94
Senna siamea	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Spondias mombin	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Streblus asper	0.72	0.24	0.00	0.00	0.00	0.00	0.00	0.97
Swietenia mahagoni	12.32	4.83	0.72	0.00	0.00	0.00	0.00	17.87
Syzygium fruticosum	0.97	0.24	0.00	0.00	0.00	0.00	0.00	1.21
Syzygium grandae	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.24
Tectona grandis	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.48
Trewia nudiflora	0.24	1.45	0.24	0.24	0.00	0.00	0.00	2.17
Ziziphus jujube	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Total	48.79	35.51	11.35	2.66	0.48	0.48	0.72	100

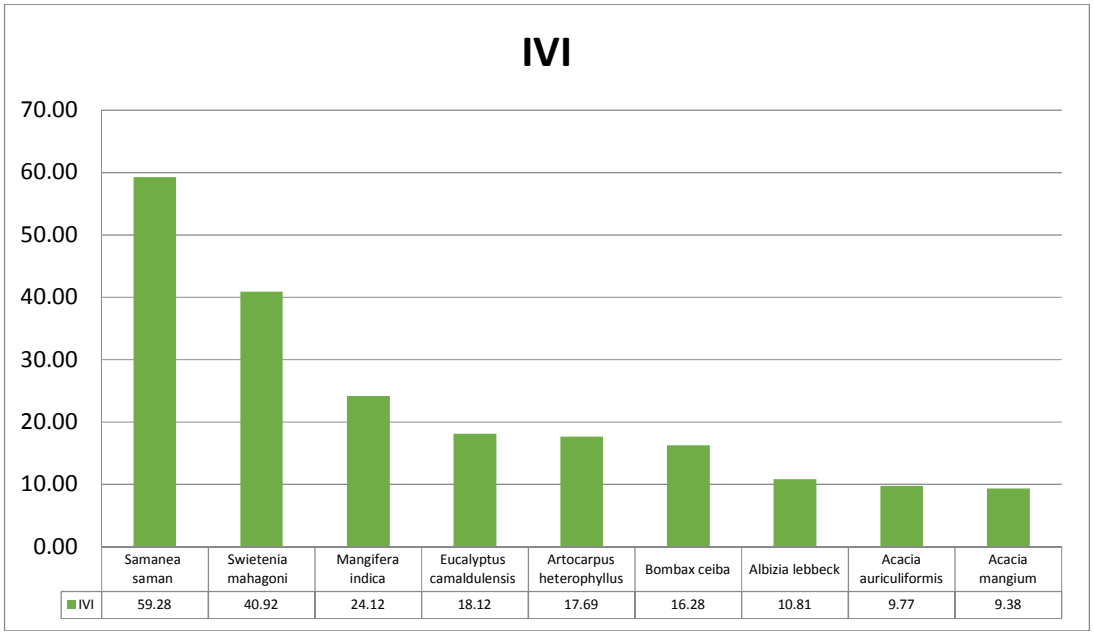

Fig. 2. Important Value Index (IVI), distribution of the riparian tree species of Halda midstream

4. DISCUSSION

The composition and diversity status are the important factors for the judgement of a forest status. In the riparian midstream area of Halda River, a total of 36 tree species belonging to 15 families were recorded in which53.33% of the families are represented by one species, 20% of the families by three species, 13.33% of the families by four species and only 6.66% of the families represented by two and the rest of 6.66% by nine tree species. The findings showed a moderate species composition compared to a study conducted by Wittmann and his team where 46 species belonging to 26 families were identified in Riparian forest area [27].

The higher IVI possessing species *Samanea saman*, *Swietenia mahagoni, Mangifera indica*, *Eucalyptus camaldulensis* and *Artocarpus heterophyllus* indicating the most abundant species and *Ziziphus jujube, Spondias mombin, Aphanamixis polystachya, Elaeocarpus serratus* and *Cassia fistula* as the rarest species of the midstream of Halda River.

The distribution of tree individuals among different height classes showed a reverse U-shaped curve. That means, as the height class increases, the number of individuals and species are reducing and indicates that old, mature trees are very scarce in the study area (Fig. 3).

Again, the height distribution of tree species revealed an almost reverse J-shaped curve (Fig. 4). The number of species and percentage of tree individuals were maximum in the lower DBH ranges and the number of tree individuals is progressively decreasing with the increase of DBH. These indicate that most of the tree stems are young and old growth stems already disappeared from the riparian area.

As the species diversity is determined not only by the number of species within a biological community but also by the relative abundance of individuals in that community, so from the general observation of the diversity indices the following discussions could be given.

The value of Shannon-Wienners Diversity Index 2.86 which generally indicates a relatively diversity rich area as the value of this index range between 1.5 to 3.5 [25] but as Shannon-Wienners Diversity Index is used while comparing the diversity of two different land areas, the value was found richer comparing to the riparian forest of the lower Miranda River which value was found between 0.75 and 2.17(mean: 1.43 ± 0.39) [27].

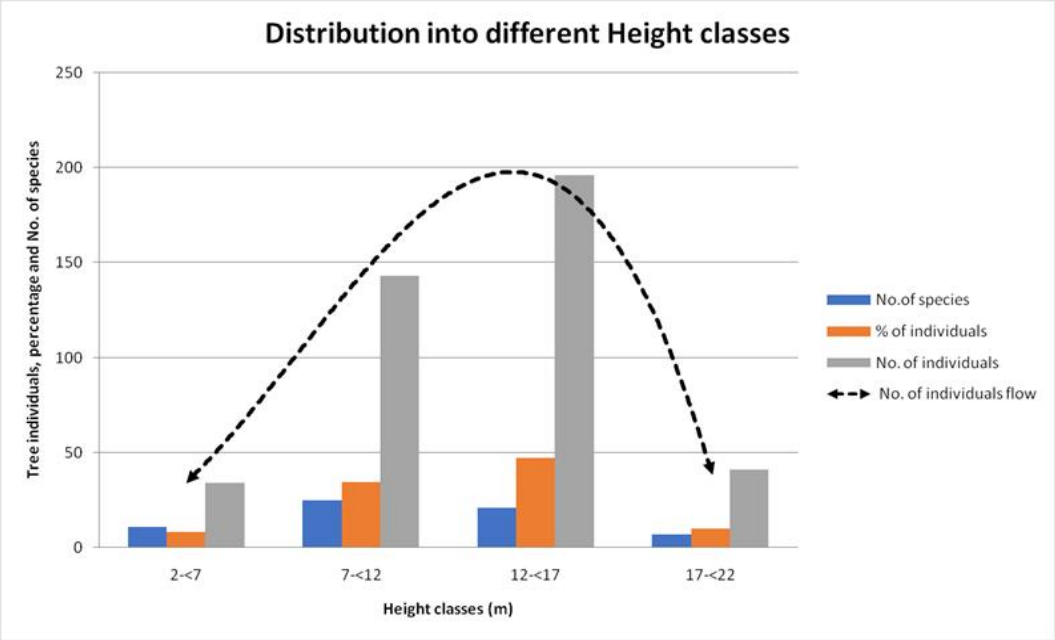

Fig. 3. Vertical distribution of tree species and individuals into different height classes

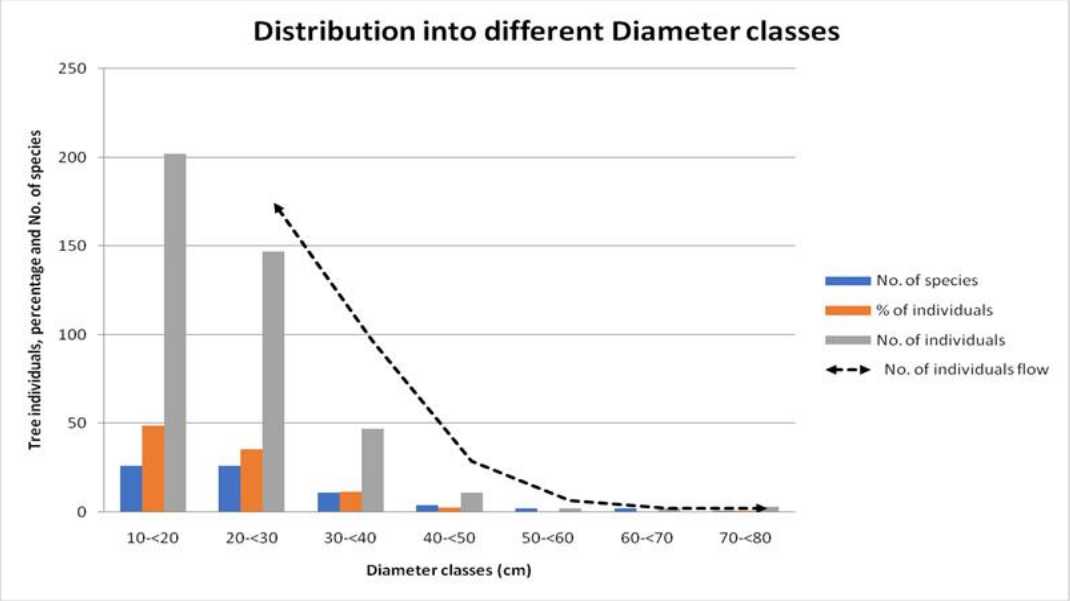

Fig. 4. Distribution of tree species, number and percentage of tree individuals into different diameter classes

Then, Simpson's diversity index was found 0.91 which indicates a high diversity of riparian tree species of Halda as its value is closer to 1 and it also shows that if two individual species would be given randomly from the quadrants there would be 91% possibility to find them of different species [26].

The Margalef's Richness Index (5.81) and Menhinick's richness index (1.77) which indicates the number of species or richness of species along with Pielou's Species Evenness Index (0.80) which ranges from (0-1) and which shows the relative abundance indicating the riparian Halda midstream as a high diversity area.

5. CONCLUSIONS

Halda River is one the most resourceful river in Bangladesh not only for the hosting of major Indian carps but also for a number of hydrology related ecosystem services. In this study, the riparian tree vegetation was investigated through direct measurement of tree species. In the study area, tree species such as fruit species, woody and timber species were found which indicates that the riparian area plays important role from both ecological and economic point of view providing food, fuel-wood, timber, and edible fruits for the surrounding local people. It was also revealed that tree species with diameter at breast height of 10-<20 cm was the most dominant. Besides, dominant tree species was with a height of 12-<17 m. It is important to mention here that this research has some limitations. The present study was conducted only in the middle stream of the Halda river basin. As Halda is a 98 km long river, the future research should focus on the whole river basin including both the upstream and lower stream of the Halda river system. Particularly future research should investigate how the tree species diversity has been changing over the changing time and environmental conditions. Despite of limitations, this composition and quantitative information of the tree species will be helpful to the policy makers, conservationists and river managers in formulating and implementing future forest resources conservation programs of Halda riparian vegetation. Therefore, a proper strategy for the conservation and management in the study area is required to the best utilization of riparian tree species by the local villagers. It is expected that the information generated through this research will be interesting to study more representatives of riparian plant communities from other type of forest that exist in Bangladesh to know more about these plant communities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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