Original Research Article

The riparian tree species composition and diversity of the midstream of HaldaRiver in Chittagong, Bangladesh

Md. Humayain Kabir[1], Hillol Barua[2]

[1]Assistant Professor, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh, Email: mhkabir@cu.ac.bd

[2]MS student, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh

Abstract

Riparian vegetation has been depleting in the many river basins of Bangladesh. Consequently, this study assessed thetree species composition, structure and diversity of the midstream area of the HaldaRiver 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. Fabaceaewas the most represented family withnine 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.*Samaneasaman* was found to be dominant, showing a maximum IVI, followed by *Swieteniamahagoni*, *Mangiferaindica*, *Eucalyptus camaldulensis*and *Artocarpusheterophyllus*. The findings of the study will be helpful for the posterior researchers in their research work andtheir 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.

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, Bangladeshneed 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(3,4).

The riparian tree species play an important role in the reduction of river bank erosion which contributes to the maintenance of the river depth(Van et al. 2004). 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 (10). The conservation of Halda river in cooperation with river-dependent community was o investigatedby Kabir et al.(2015). Studies were also done on the spawning of major Indian

carp(12), while the biodiversity status of carps in the river assessed via their distribution and most important zones of spawning (13). Bhuyan and Bakar(2017) looked at the sediment and the heavy metal contamination in the water of the HaldaRiver. Zaman (2014) focused a research project on awakening local people who are dependent on this river.

Despite of all these studies above mentioned, the tree vegetation on the two banks of this river which is the most important component of HaldaRiver ecosystem is still unexplored.Therefore, this investigation assessed the tree species compositionand 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 (Kabir et al. 2013) which originates from the Batnatali Hill Ranges of RamgarhUpazila under Khagrachari District, Bangladesh. It flows through Fatikchhari, Hathazari and RaozanUpazilas and Chandgaon Thana of Chittagong before ending into the Karnaphuli River. It is the only natural spawning ground of Indian major carp species (Kabir et al., 2015).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(14). 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' northlatitude &91°50'43.224" to 91°47'51.936" eastlongitudes(**Figure 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(15). 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 sizewere 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 **(Figure 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.

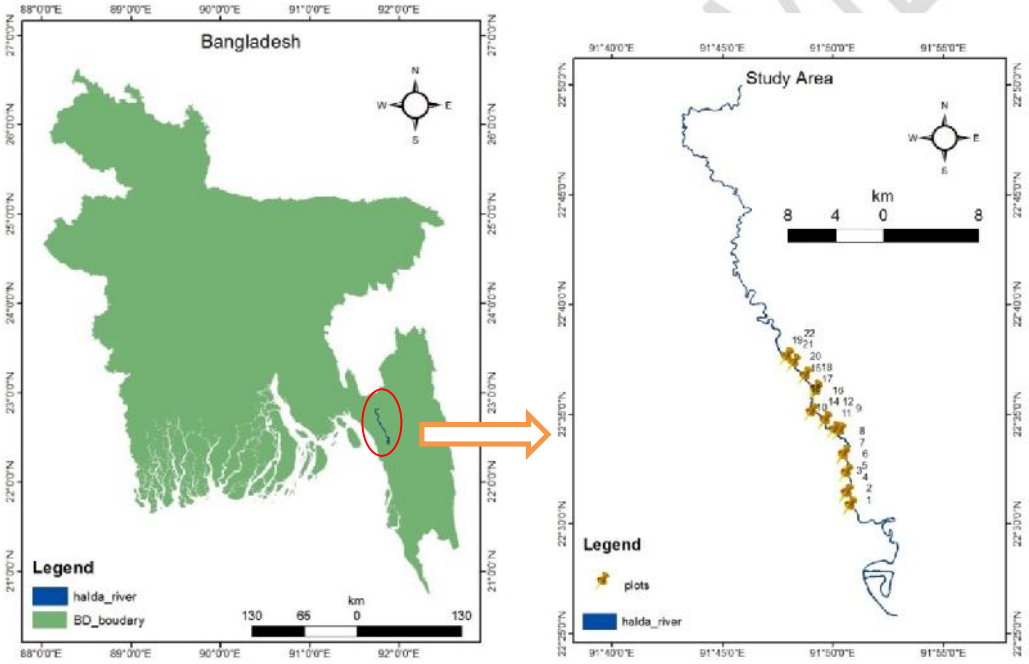


Figure 1 Map of the study area of Halda river

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(16):

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 following the methods developed by (17). Identified plants were arranged taxonomically and categorized according to their habit form.

I. Frequency and relative frequency (%):

Frequency of a species = $\frac{Total no. of quadrate in which the species occurs}{Total number of quadrats studied}$

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

II. Density and relative density(%):

Density of a species = $\frac{Total no. of individuals of a species in all quadrats}{Total no. of sample plots of all species}$

Relative density of a species = $\frac{Total no. of individuals of the species}{Total no. of individuals of all species} \times 100$

III. Abundance and relative abundance (%)

Abundance of a species = $\frac{Total no. of individuals of a species in all the quadrats}{Total no. of quadrats in which the species occured}$

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(18).

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 (19). 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 i.e., 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(20).

Four diversity indices, i.e. 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) were analyzed as following (Margalef 1958; Pielou 1984; Shannon & Weiner 1963a; Simpson 1949a) respectively to get a picture of tree species diversity in Halda river.

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. 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 (Shannon & Weiner 1963).

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 madeup of species i

S = Numbers of species encountered

$\sum$ = 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 (22)

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 (21).

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 usingthe formulae 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 distributionThe tree individuals were categorized into 4 height classes and a total of 414individuals having (DBH) ≥10cm were categorized into 7 diameterclasses 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 *Swieteniamahagoni, Samaneasaman, Mangiferaindica, Areca catechu, Artocarpusheterophyllus, Albizialebbeck, 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, Bombax ceiba* for meeting fruit, fuel, timber needs.

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	*Mangiferaindica*	Aam	33
		2	*Spondiasmombin*	Amra	1
		3	*Lanneacoromandelica*	JiolBadi	8
2	Apocynaceae	1	*Alstoniascholaris*	Chatim	1
3	Arecaceae	1	*Areca catechu*	Supari	21
		2	*Cocosnucifera*	Narikel	9
		3	*Borassusflabellifer*	Tal	1
4	Bombacaceae	1	*Bombaxceiba*	Shimul	13
5	Dipterocarpaceae	1	*Dipterocarpusturbinatus*	TeliyaGarjan	1
6	Elaeocarpaceae.	1	*Elaeocarpusserratus*	Jalpai	1
7	Euphorbiaceae	1	*Trewianudiflora*	pitali	9
8	Fabaceae	1	*Samaneasaman*	Raintree	66
		2	*Acacia auriculiformis*	Akashmoni	15
		3	*Acacia mangium*	Mangium	14
		4	*Erythrinavariegata*	Mandar	6
		5	*Albizialebbeck*	Kalokoroi	16
		6	*Albiziaprocera*	Sadakoroi	6
		7	*Sennasiamea*	Minjiri	1
		8	*Albiziaodoratissima*	Tetuakoroi	2
		9	*Cassia fistula*	Sonalu	1
9	Lythraceae	1	*Lagerstroemia speciosa*	Jarul	10

10	Meliaceae	1	*Swieteniamahagoni*	Mahagoni	74
		2	*Aphanamixispolystachya*	Pitraj	1
		3	*Khayaanthotheca*	Lombu	7
Sl. No.	**Family**	**Sl. No.**	**Binomial name**	**Local name**	**No. of individual**
10	Meliaceae	4	*Chukrasiatabularis*	Chikrashi	4
11	Moraceae	1	*Artocarpusheterophyllus*	Kanthal	20
		2	*Ficusbenghalensis*	Bot	2
		3	*Streblusasper*	Sheora	4
		4	*Artocarpuslacucha*	Borta	4
12	Myrtaceae	1	*Eucalyptus camaldulensis*	Eucalyptus	42
		2	*Syzygiumgrandae*	Dhakijam	1
		3	*Syzygiumfruticosum*	Puti jam	5
13	Rhamnaceae	1	*Ziziphusjujuba*	Boroi	1
14	Rubiaceae	1	*Neolamarckiacadamba*	Kadam	7
15	Verbenaceae	1	*Gmelinaarborea*	Gamar	5
		2	*Tectonagrandis*	Shegun	2

219

220

221 **Table 2 List of tree species with stem density per hectare recorded from Halda riparian**
222 **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	*Albizialebbeck*	16	18.18
4	Tetuakoroi	*Albiziaodoratissima*	2	2.27

5	Sadakoroi	*Albiziaprocera*	6	6.82
6	Chatim	*Alstoniascholaris*	1	1.14
7	Pitraj	*Aphanamixispolystachya*	1	1.14
8	Supari	*Areca catechu*	21	23.86
9	Kanthal	*Artocarpusheterophyllus*	20	22.73
10	Borta	*Artocarpuslacucha*	4	4.55
11	Shimul	*Bombaxceiba*	13	14.77
12	Tal	*Borassusflabellifer*	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	*Erythrinavari egata*	6	6.82
Serial number	**Local name**	**Binomial name**	**No. of individual**	**Stem/ha**
19	Eucalyptus	*Eucalyptus camaldulensis*	42	47.73
20	Bot	*Ficus benghalensis*	2	2.27
21	Gamar	*Gmelinaar borea*	5	5.68
22	Lombu	*Khaya anthotheca*	7	7.95
23	Jarul	*Lagerstroemia speciosa*	10	11.36
24	Jiolbadi	*Lanneacoro mandelica*	8	9.09
25	Aam	*Mangifera indica*	33	37.50

26	Kadam	*Neolamarckia cadamba*	7	7.95
27	Raintree	*Samanea saman*	66	75.00
28	Minjiri	*Sennasiamea*	1	1.14
29	Amra	*Spondiasmombin*	1	1.14
30	Sheora	*Streblusasper*	4	4.55
31	Mahagoni	*Swieteniamahagoni*	74	84.09
32	Puti jam	*Syzygiumfruticosum*	5	5.68
33	Dhakijam	*Syzygiumgrandae*	1	1.14
34	Shegun	*Tectonagrandis*	2	2.27
35	Pitali	*Trewianudiflora*	9	10.23
36	Boroi	*Ziziphusjujuba*	1	1.14

223

224

225 **3.2 Diversity Indices**

226 Among the diversity indices, 2.86 was found for Shannon-Wienners Diversity Index where
227 Simpson's Dominance Index was 0.91. Moreover, Margalef's Richness Index was calculated
228 as 5.81, Pielou's Species Evenness Index was 0.80 and Menhinick's richness index was
229 1.77(**Table 3**).

230

231 **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

232

233

234 **3.3 Importance Value Index (IVI) of Riparian Halda tree species**

235 Importance Value Index (IVI) of the tree species was assessed along with basal area (BA),
236 Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo) of each species.
237 *Samaneasaman* possessed the highest IVI (59.28%) followed by 40.92% of
238 *Swieteniamahagoni*, 24.12% by *Mangiferaindica*, 18.12% by *Eucalyptus camaldulensis*and
239 17.69% by *Artocarpusheterophyllus* shown in (**Table 4 and Figure 2)**.

240

241 **Table 4 Phytosociological attributes of the recorded tree species from the 22 quadrats**
242 **in riparian Halda**[Here, RD = Relative density, RF = Relative Frequency, RA = Relative
243 Abundance, RDo = Relative Dominance, IVI = Importance Value Index]

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	*Albizialebbeck*	Kalokoroi	0.94	3.86	2.04	6.47	4.90	10.81
4	*Albiziaodoratissima*	Tetuakoroi	0.09	0.48	0.68	2.43	0.46	1.63
5	*Albiziaprocera*	Sadakoroi	0.28	1.45	2.04	2.43	1.47	4.96
6	*Alstoniascholaris*	Chatim	0.05	0.24	0.68	1.21	0.28	1.20
7	*Aphanamixispolystachya*	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	*Artocarpusheterophyllus*	Kanthal	1.03	4.83	7.48	2.21	5.38	17.69
10	*Artocarpuslacucha*	Borta	0.17	0.97	2.72	1.21	0.90	4.59

11	*Bombaxceiba*	Shimul	1.34	3.14	6.12	1.75	7.01	16.28
12	*Borassusflabellifer*	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	*Chukrasiatabularis*	Chikrashi	0.16	0.97	2.04	1.62	0.83	3.83
15	*Cocosnucifera*	Narikel	0.42	2.17	2.72	2.73	2.18	7.07
16	*Dipterocarpusturbinatus*	Teliyagarjan	0.05	0.24	0.68	1.21	0.25	1.17
17	*Elaeocarpusserratus*	Jalpai	0.02	0.24	0.68	1.21	0.12	1.04
18	*Erythrinavariegata*	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	*Ficusbenghalensis*	Bot	0.12	0.48	1.36	1.21	0.61	2.46
Sl. No.	**Binomial name**	**Local name**	**BA (m)**	**RD (%)**	**RF (%)**	**RA (%)**	**RDo (%)**	**IVI**
21	*Gmelinaarborea*	Gamar	0.29	1.21	2.04	2.02	1.54	4.79
22	*Khayaanthotheca*	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	*Lanneacoromandelica*	Jiolbadi	0.19	1.93	3.40	1.94	0.99	6.33
25	*Mangiferaindica*	Aam	1.91	7.97	6.12	4.45	10.03	24.12
26	*Neolamarckiacadamba*	Kadam	0.38	1.69	2.72	2.12	1.98	6.39
27	*Samaneasaman*	Raintree	5.80	15.94	12.93	4.22	30.41	59.28
28	*Sennasiamea*	Minjiri	0.06	0.24	0.68	1.21	0.29	1.21
29	*Spondiasmombin*	Amra	0.01	0.24	0.68	1.21	0.06	0.99
30	*Streblusasper*	Sheora	0.11	0.97	2.04	1.62	0.58	3.59
31	*Swieteniamahagoni*	Mahagoni	2.06	17.87	12.24	4.99	10.81	40.92
32	*Syzygiumfruticosum*	Puti jam	0.13	1.21	2.04	2.02	0.70	3.95

33	*Syzygiumgrandae*	Dhakijam	0.10	0.24	0.68	1.21	0.53	1.46
34	*Tectonagrandis*	Shegun	0.10	0.48	0.68	2.43	0.52	1.68
35	*Trewianudiflora*	Pitali	0.58	2.17	2.04	3.64	3.02	7.24
36	*Ziziphusjujube*	Boroi	0.01	0.24	0.68	1.21	0.06	0.99

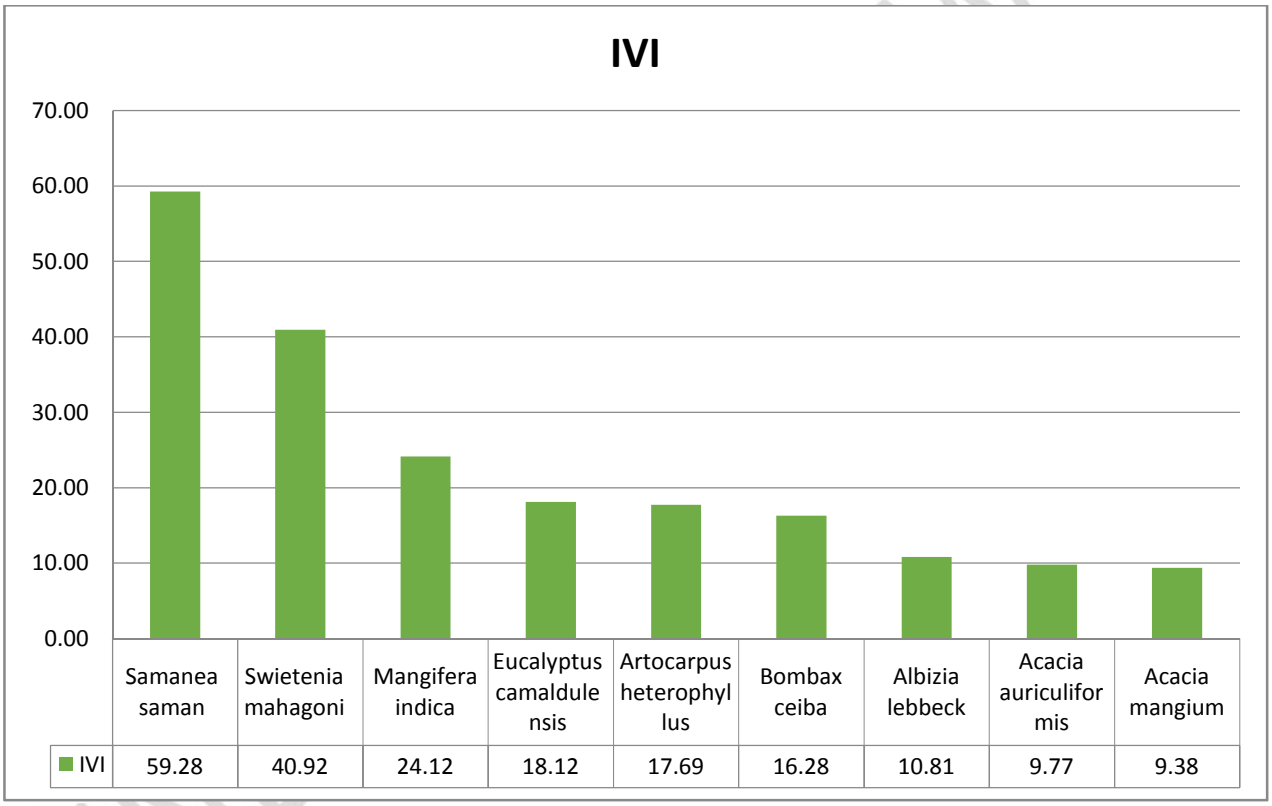


Figure 2 Important Value Index (IVI), distribution of the riparian tree species of Halda midstream.

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 ree 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.

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
Albizialebbeck	0.00	0.24	0.97	2.66	3.86
Albiziaodoratissima	0.00	0.48	0.00	0.00	0.48
Albiziaprocera	0.00	0.24	1.21	0.00	1.45
Alstoniascholaris	0.00	0.24	0.00	0.00	0.24
Aphanamixispolystachya	0.00	0.24	0.00	0.00	0.24
Areca catechu	0.00	0.48	4.59	0.00	5.07
Artocarpusheterophyllus	0.97	3.14	0.72	0.00	4.83
Artocarpuslacucha	0.00	0.24	0.72	0.00	0.97
Bombaxceiba	0.00	0.97	1.45	0.72	3.14
Borassusflabellifer	0.00	0.24	0.00	0.00	0.24
Cassia fistula	0.00	0.24	0.00	0.00	0.24

Chukrasiatabularis	0.00	0.00	0.97	0.00	0.97
Cocosnucifera	0.24	1.21	0.00	0.72	2.17
Binomial name	**% distribution of tree species into different height(m) classes**				**Total**
	2- <7 m	**7- <12 m**	**12- <17 m**	**17- <22 m**	
Dipterocarpusturbinatus	0.00	0.24	0.00	0.00	0.24
Elaeocarpusserratus	0.00	0.00	0.24	0.00	0.24
Erythrinavariegata	1.21	0.24	0.00	0.00	1.45
Eucalyptus camaldulensis	0.24	0.00	5.56	4.35	10.14
Ficusbenghalensis	0.24	0.24	0.00	0.00	0.48
Gmelinaarborea	0.00	0.00	0.97	0.24	1.21
Khayaanthotheca	0.00	1.21	0.48	0.00	1.69
Lagerstroemia speciosa	0.00	1.69	0.72	0.00	2.42
Lanneacoromandelica	1.93	0.00	0.00	0.00	1.93
Mangiferaindica	1.69	1.45	4.83	0.00	7.97
Neolamarckiacadamba	0.00	0.00	1.69	0.00	1.69
Samaneasaman	0.72	3.86	11.35	0.00	15.94
Sennasiamea	0.00	0.00	0.24	0.00	0.24
Spondiasmombin	0.24	0.00	0.00	0.00	0.24
Streblusasper	0.00	0.97	0.00	0.00	0.97

Swieteniamahagoni	0.00	12.56	5.31	0.00	17.87
Binomial name	**% distribution of tree species into different height(m) classes**				**Total**
	2- <7 m	**7- <12 m**	**12- <17 m**	**17- <22 m**	
Syzygiumfruticosum	0.00	1.21	0.00	0.00	1.21
Syzygiumgrandae	0.00	0.00	0.24	0.00	0.24
Tectonagrandis	0.00	0.00	0.00	0.48	0.48
Trewianudiflora	0.00	0.24	1.21	0.72	2.17
Ziziphusjujube	0.24	0.00	0.00	0.00	0.24
Total	8.21	34.54	47.34	9.90	100

261

262

263 **3.5 Structural composition of tree species based on diameter class distribution**

264 7 diameter classes (cm) were determined to assume the structural composition. These were
265 10- <20 cm, 20 -<30 cm, 30- <40 cm, 40- <50 cm, 50- <60 cm, 60- <70 cm and 70- <80 cm.
266 Among them, 48.79% of all the tree individuals (202 tree stems of 414 stems) belonging to
267 26 tree species were in the diameter range of 10- <20 cm (**Table 6**). Only *Samanea saman*
268 belongs to the highest dbh class 70- <80 cm.

269

270 **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	2.66	0.97	0.00	0.00	0.00	0.00	0.00	3.62

auriculiformis								
Acacia mangium	1.69	1.69	0.00	0.00	0.00	0.00	0.00	3.38
Albizialebbeck	0.24	2.66	0.97	0.00	0.00	0.00	0.00	3.86
Albiziaodoratissima	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.48
Albiziaprocera	0.00	1.45	0.00	0.00	0.00	0.00	0.00	1.45
Alstoniascholaris	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Aphanamixispolystachya	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
Artocarpusheterophyllus	1.69	1.93	1.21	0.00	0.00	0.00	0.00	4.83
Artocarpuslacucha	0.24	0.72	0.00	0.00	0.00	0.00	0.00	0.97
Bombaxceiba	0.72	0.97	0.48	0.48	0.24	0.24	0.00	3.14
Borassusflabellifer	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
Chukrasiatabularis	0.24	0.72	0.00	0.00	0.00	0.00	0.00	0.97
Cocosnucifera	0.72	1.45	0.00	0.00	0.00	0.00	0.00	2.17
Dipterocarpusturbinatus	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Elaeocarpusserratus	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Erythrinavariegata	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
Ficusbenghalensis	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.48
Gmelinaarborea	0.00	0.24	0.97	0.00	0.00	0.00	0.00	1.21
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**	
Khayaanthotheca	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
Lanneacoromandelic	1.69	0.24	0.00	0.00	0.00	0.00	0.00	1.93

a								
Mangiferaindica	3.14	2.42	1.69	0.72	0.00	0.00	0.00	7.97
Neolamarckiacadamba	0.00	1.69	0.00	0.00	0.00	0.00	0.00	1.69
Samaneasaman	3.14	6.04	4.35	1.21	0.24	0.24	0.72	15.94
Sennasiamea	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
Spondiasmombin	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Streblusasper	0.72	0.24	0.00	0.00	0.00	0.00	0.00	0.97
Swieteniamahagoni	12.32	4.83	0.72	0.00	0.00	0.00	0.00	17.87
Syzygiumfruticosum	0.97	0.24	0.00	0.00	0.00	0.00	0.00	1.21
Syzygiumgrandae	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.24
Tectonagrandis	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.48
Trewianudiflora	0.24	1.45	0.24	0.24	0.00	0.00	0.00	2.17
Ziziphusjujuba	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

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 recordedin 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 representedby two and the rest of 6.66% by nine tree species.The findings showed a moderate species composition compared to a study conductedby Wittmann and his team where 46 species belonging to 26 families were identified in Riparian forest area(26).

The higher IVI possessing species *Samaneasaman*, *Swieteniamahagoni,Mangiferaindica*, *Eucalyptus camaldulensis*and *Artocarpusheterophyllus*indicating the most abundant species

and *Ziziphus jujube, Spondiasmombin, Aphanamixispolystachya, Elaeocarpusserratus* and *Cassia fistula* as the rarest species of the midstream of HaldaRiver.

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 **(Figure 3).**

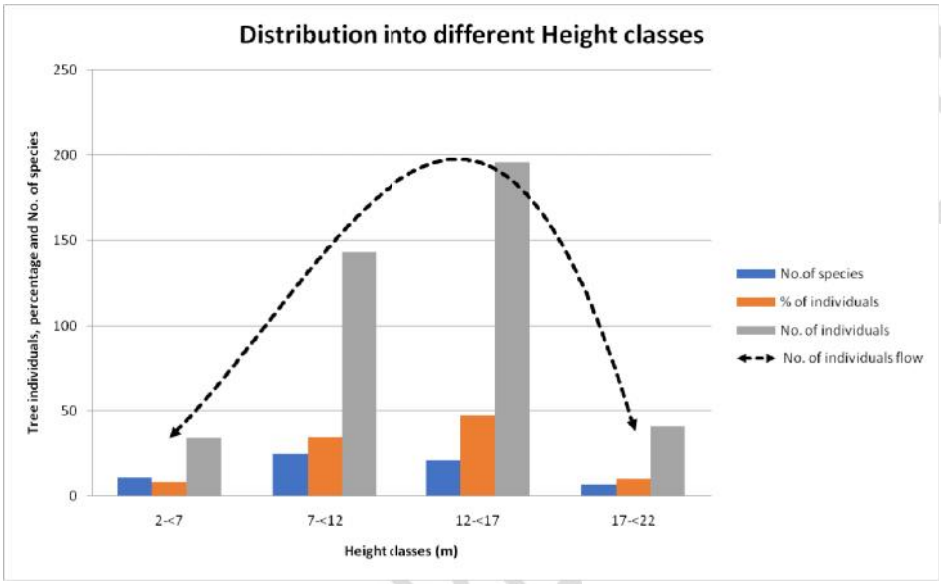
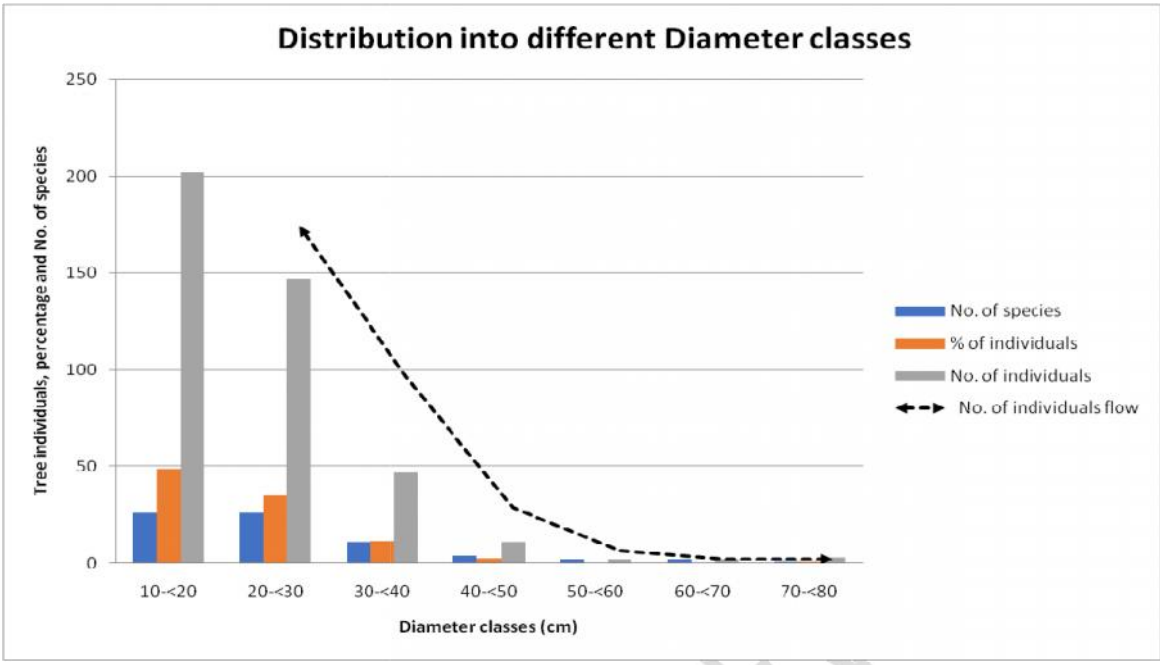


Figure 3 Vertical distribution of tree species and individuals into different height classes

Again,the height distribution of tree species revealed an almost reverse J-shaped curve **(Figure 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.



299

300 **Figure 4** Distribution of tree species, number and percentage of tree individuals into
301 differentdiameter classes

302

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

306 The value of Shannon-Wienners Diversity Index 2.86 which generally indicates a relatively
307 diversity rich area as the value of this index range between 1.5 to 3.5 (Shannon & Weiner
308 1963c) but as Shannon-Wienners Diversity Index is used while comparing the diversity of
309 two different land areas, the value was found richer comparing to theriparian forest of the
310 lower Miranda River which value was found between 0.75 and 2.17(mean: 1.43 ± 0.39)(26).

311 Then, Simpson's diversity index was found 0.91 which indicates a high diversity of riparian
312 tree species of Halda as its value is closer to 1 and it also shows that if two individual species
313 would be given randomly from the quadrants there would be 91% possibility to find them of
314 different species (Simpson 1949b).

315 The Margalef's Richness Index (5.81) and Menhinick's richness index (1.77) which indicates
316 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.

References (not in accordance to journal guidelines!)

1. Hitzhusen FJ, Kruse SA, Abdul-Mohsen A, Ferreti-Meza JJ, Hnytka M. 11. The Cuyahoga River Valley initiative: framing, codification, and preliminary economic analysis in an urban river corridor. Economic valuation of river systems. 2007;174.

2. BikashDey A. Halda in peril. The Daily Star [Internet]. 2017 Feb 4 [cited 2018 May 16]; Available from: https://www.thedailystar.net/city/halda-peril-1355791

3. Belsky AJ, Amundson RG, Duxbury JM, Riha SJ, Ali AR, Mwonga SM. The effects of trees on their physical, chemical and biological environments in a semi-arid savanna in Kenya. Journal of applied ecology. 1989;1005–1024.

4. Van De Wiel MJ, Darby SE. Numerical Modeling of Bed Topography and Bank Erosion Along Tree-Lined Meandering Rivers. Riparian vegetation and fluvial geomorphology. 2004;267–282.

5. Cho MJ, Schnabel R. Group contribution data obtained by ion-pair extraction of prostaglandin B2 with aliphatic amines. J Pharm Sci. 1975 Nov;64(11):1894–6.

7. Bhuyan M, Bakar M. Assessment of water quality in Halda River (the Major carp breeding ground) of Bangladesh. Vol. 3. 2017. 429 p.

9. Islam M, Akbar A, Akhtar A, Kibria, Bhuyan M. WATER QUALITY ASSESSMENT ALONG WITH POLLUTION SOURCES OF THE HALDA RIVER. Vol. 43. 2017. 61 p.

11. Kabir H, Kibria M, Jashimuddin M, Hossain MM. Conservation of a river for biodiversity and ecosystem services: the case of the Halda – the unique river of Chittagong, Bangladesh. International Journal of River Basin Management. 2015 Jul 3;13(3):333–42.

12. Tsai C, Islam MN, Karim R, Rahman KS. Spawning of major carps in the lower Halda River, Bangladesh. Estuaries. 1981;4(2):127–138.

14. Patra R, Azadi M. Limnology of the Halda River. Vol. 2. 1985. 31 p.

15. Chowdhury M, Hasan ME, Abdullah-Al-Mamun MM. Land use/land cover change assessment of Halda watershed using remote sensing and GIS. The Egyptian Journal of Remote Sensing and Space Science [Internet]. 2018 Dec 13 [cited 2019 Jan 28]; Available from: http://www.sciencedirect.com/science/article/pii/S1110982318300140

16. Thakur NS, Gupta NK, Gupta B. VOLUME AND BIO MASS PREDICTION MIO DELS FOR 4 C4 CI 4 C4 TECH U WILLID. IN AGRO FORESTRY SYSTEMIS OF NORTH-WEST HIMALAYA. Journal of Non-Timber Forest Products Vol. 2008;15(1):1–9.

18. Dhaulkhandi M, Dobhal A, Bhatt S, Kumar M. Community structure and regeneration potential of natural forest site in Gangotri, India. Journal of Basic and Applied sciences. 2008;4(1):49–52.

19. Petchey OL, Gaston KJ. Functional diversity: back to basics and looking forward. Ecology letters. 2006;9(6):741–758.

20. Colin P. Biogeographic region [Internet]. Encyclopedia Britannica. 2018 [cited 2018 May 16]. Available from: https://www.britannica.com/science/biogeographic-region

21. Margalef R. Information theory in ecology. General systems. 1958;3:36–71.

22. Pielou EC. The interpretation of ecological data: a primer on classification and ordination. John Wiley & Sons; 1984.

23. Shannon CE, Weiner W. The mathematical theory of communication Urban University Illinois Press. 125pp. 1963;

24. Simpson EH. Measurement of diversity. Nature. 1949;

25. Shannon CE, Weiner W. The mathematical theory of communication Urban University Illinois Press. 125pp. 1963;

26. Wittmann F, Zorzi BT, Tizianel FAT, Urquiza MVS, Faria RR, e Sousa NM, et al. Tree Species Composition, Structure, and Aboveground Wood Biomass of a Riparian Forest of the Lower Miranda River, Southern Pantanal, Brazil. Folia Geobotanica. 2008 Dec 2;43(4):397.

27. Shannon CE, Weiner W. The mathematical theory of communication Urban University Illinois Press. 125pp. 1963;

28. Simpson EH. Measurement of diversity. nature. 1949;163(4148):688.

29. Hitzhusen FJ, Kruse SA, Abdul-Mohsen A, Ferreti-Meza JJ, Hnytka M. 11. The Cuyahoga River Valley initiative: framing, codification, and preliminary economic analysis in an urban river corridor. Economic valuation of river systems. 2007;174.

30. Akhter F. Change of Halda river flow due to different water control structures and its impact on Halda ecosystem. 2015 Dec [cited 2019 Jan 29]; Available from: http://lib.buet.ac.bd:8080/xmlui/handle/123456789/4657

31. Pielou EC. Species-diversity and pattern-diversity in the study of ecological succession. Journal of theoretical biology. 1966;10(2):370–383.