Original Research Article

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

Abstract

The study was conducted to assess the tree species composition and diversity of the midstream area of the Halda river. Total number of 22 quadrats (20m × 20m in size) was sampled systematically. A total of 414 individual tree stems of ≥10 cm DBH of 36 tree species belonging to 31 genera and 15 families were enumerated. Fabaceae family was represented by maximum number of tree species (9) followed by Moraceae, Meliaceae and Anacardiaceae. Density, Basal area and volume of the tree species were 470.45 stem/ha, 19.09m²/ha and 139.42m³/ha respectively. Among the tree species *Samanea saman* was found dominant showing maximum IVI followed by *Swietenia mahagoni*, *Mangifera indica*, *Eucalyptus camaldulensis* and *Artocarpus heterophyllus*. Different diversity indics, i.e Shannon-Wienners Diversity Index, Simpson's Dominance Index, Pielou's Species Evenness Index, Margalef's and Menhinick's richness index were calculated and which indicating a rich tree species diversity of riparian Halda midstream. The findings of the study will be helpful for the posterior researchers in their research work as well as 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.

Keywords: Species composition, Diversity, Riparian tree species, Halda River

1. Introduction

Rivers are the prominent and important feature of the landscape which play very crucial roles in the development of any country. Any country's economy and development are greatly dependent on the productions and service that provide a river such as fresh water supply, fish production, transportation, waste assimilation etc., along with provision of a wide array of recreation and tourism options (Hitzhusen et al. 2007). 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 Ramgarh Upazila under Khagrachari District, Bangladesh. It flows through Fatikchhari, Hathazari and Raozan Upazilas and Chandgaon Thana of Chittagong before ending into the Karnaphuli River. It is the only natural spawning ground of Indian major carp species (Tsai et al. 1981). As a nationally important river its resources need to be conserved. However, this river is vulnerable due to many natural and anthropogenic factors. Different man made activities such as industrial discharge, tobacco farming, rubber dam construction, brick-field construction, illegal quarry of sands etc. continue to threaten its existence (Dey 2017). Besides, the riverbank erosion, increase of salinity in the river now threatens the livelihood of several thousand fishermen and egg collectors. On the other hand, industrial effluents including chemicals of tea gardens are regularly dumping in the river causing serious damage of the river (Dey 2017). Some of these threatening and destructive factors i.e. riverbank erosion, wastage, salinity and river depth control etc. can be maintained by a proper management of the riverbank tree species (Belsky et al. 1989; Wiel and Darby 2004). 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 (Cho and Schnabel 1975; Cerqueira et al. 2014).

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(Bhuyan and Bakar 2017) and the pollutants discharged into the Halda River through major canals were also investigated (Islam et al. 2017). The river flow of Halda is important and its impact on halda ecosystem was also estimated (Akhter 2015). The

conservation of Halda river in cooperation with river-dependent community was also investigated (Kabir et al. 2015). Studies were also done on the spawning of major Indian carp(Tsai et al. 1981) and the biodiversity status of carps the river which assessed the distribution of carps and most important zone of spawning (Ferdous 2015). The sediment analysis and the heavy metal contamination in the water of Halda river is an important work in maintaining the quality of the water in the feasible proportion which was also assessed (Bhuyan and Bakar 2017). Recently, Zaman (2014) focused a research project on awakening local people who are dependent on this river and developed a research training and awareness centre (Zaman 2014). Despite of all these studies mentioned above, the tree species composition on the bank of the river which is the most important component of Halda river ecosystem was still unexplored although it is directly associated to the other components such as soil, water, biodiversity of the Halda River ecosystem. Therefore, this work is done to assess the tree species composition, structure and diversity of the midstream area of the river bank. The specific objectives of this study are:

- To prepare a tree species database of the midstream of Halda riparian area.
- To assess the composition and diversity of available riparian tree species.
- To determine the relative frequency, relative density, abundance, relative dominance and importance value index of each tree species in order to characterize the structure of the vegetation.
- To find out the relative distribution of each tree species in different DBH (diameter at breast height) and height classes.

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. The 98 km long river has a very turbulent tributary, the Dhurung River, which joins at Sundarpur about 48.25 km downstream (Kabir et al. 2015). Halda, the third main river of Chittagong after the Karnaphuli and the Sangu, is such a resourceful river of Bangladesh(Kabir et al. 2013). It originates from Halda chora at the area of 2 no. Patachora union in Ramgarh Upazila under Khagrachari District (Former Chittagong Hill Tracts), Bangladesh. It is the only pure Indian major carp breeding field of Bangladesh (Tsai et al. 1981) perhaps in South Asia. Garduara point at the mouth of Boalia and Cheng-khali tributary of Halda River was selected by taking into consideration that the site will give shelter a large number of fishes because it is the conjoined area where the Halda river meets with Boalia and Cheng khali tributary. The study was conducted in the midstream of Halda river (from Nazirhat, Fatikchhari to Sattarghat, Raojan) (**Figure 1**). The total length of the midstream area of this river from Nazirhat to Shattarghat is about 19.6 km.

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 2km (approx.) interval two sampling plots of 20m×20m on the both sides of the river were taken. A total of 22 plots were taken on each sides of the river **(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.

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 (Chaturvedi and Khanna 1982; Thakur et al. 2008):

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 Williams (1991). 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) (Dhaulkhandi et al. 2008) and (Whittaker & Feeny 1971).

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 (Petchey & Gaston 2006). 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(Colin 2018).

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 made up 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 (Pielou 1984)

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

196 Margalef's richness index (R) is high in communities that include a greater number of species
197 and in which the number of individuals of each species decreases relatively slowly on passing
198 from the more abundant to the less abundant ones (Margalef 1958).

199 **IV. Pielou's Species Evenness Index**

200 It is measured by the following equation:

201 $$E = \frac{H}{Ln(S)}$$

202 Where, E = Species Evenness

203 H = The Shanon-Weinner's biodiversity Index

204 S= Total number of species

205 **V. Menhinick's richness index**

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

208 $$DI = \frac{S}{\sqrt{N}}$$

209 Where, DI= Menhinick's richness index

210 S=No. of species

211 N=No. of total species

212

3. RESULTS AND DISCUSSIONS

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. (**Table 1 and Table 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. Total Basal area and volume of all the recorded tree species were calculated as 19.09m²/ha and 139.42m³/ha respectively.

Homestead and plantation these two types of land class were found on the bank of the river where *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 for family.

3.2 Diversity Indices

Different diversity indices, i.e Shannon-Wienner Diversity Index (H), Margalef 's richness index (R), Simpon's Dominance Index (D), Pielou's Species Evenness Index (E) and Menhinick's richness index(DI) were calculated to depict tree species diversity of the study area (**Table 3**). Among these, 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.

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 (Shannon & Weiner 1963c) but as Shannon-Wienners Diversity Index is used while comparing the diversity of

two different land areas, the value was found poorer comparing by Sithapahar reserve forest(Nath et al., 2000) and Tankawati natural forest of Chittagong (South) Forest Division (Motaleb & Hossain 2011) where the value is 2.98 and 3.25 respectively. The index is also lower in comparison to Shanon-Wiener's diversity index of 4.449 in Dhudpukuria-Dhopachori Wildlife Sanctuary (Hossain et al. 2013).

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 (Simpson 1949b).

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.

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 Figure 2)**.

From the value of IVI, 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 **(Figure 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, viz. 2- <7m, 7- <12m, 12- <17m, and 17- <22m (**Table 5**). A total of 448 tree stems per ha were considered for height class distribution. Maximum (47.34%) tree individuals belongs to height class 12- <17m followed by 7- <12m (34.54%) and 17- <22m height class (9.90%). The lowest percent (8.21%) of trees occurred in highest

height class 2- <7m range. Number of tree species, % of the tree individuals and number of tree individuals showed that maximum species occurred in height class of 12- <17m.

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).**

3.5 Structural composition of tree species based on diameter class distribution

All the recorded 414 tree stems having dbh of ≥10cm were distributed into seven diameter classes (cm), e.g. 10- <20cm, 20 -<30cm, 30- <40cm, 40- <50cm, 50- <60cm,60- <70cm and 70- <80cm. 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- <20cm (**Table 6 & Figure 4**). Only *Samanea saman* belongs to the highest dbh class 70- <80cm.

The number of tree individuals is progressively decreasing with the increase of dbh. This 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. These indicate that most of the tree stems are young and old growth stems already disappeared from the riparian area.

4. Conclusions

Halda river is one of the most resourceful rivers in Bangladesh. This river provides a number of products and services all-round the year to the communities living its vicinity. This research was conducted to assess the composition and diversity of tree species which is one of the most important elements of Halda river ecosystem. The complete tree species composition of the midstream Halda riparian area was recorded through intensive field visits with direct measured. Besides, tree species diversity was calculated in the midstream of Halda. We found a total of 36 tree species under 31 genera and 15 families. In the study area, tree species like 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.

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 of Halda riparian vegetations. Therefore, a proper strategy for the conservation and management in the study site is required to the best utilization of riparian tree species by the local villagers. This information 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.

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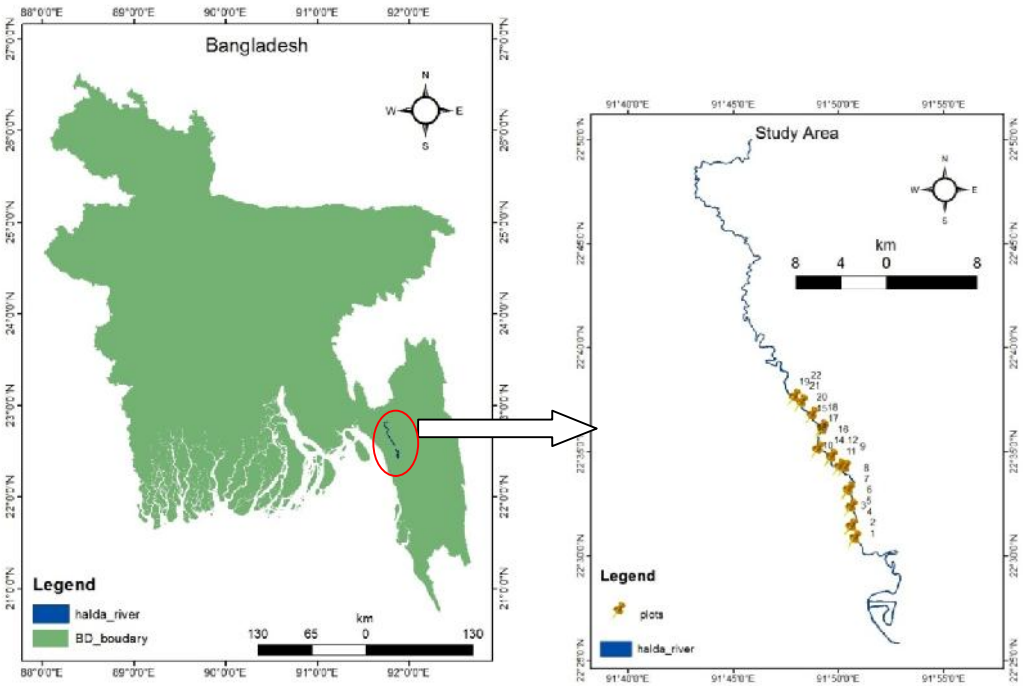

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416 **Figure 1** Map of the study area of Halda river

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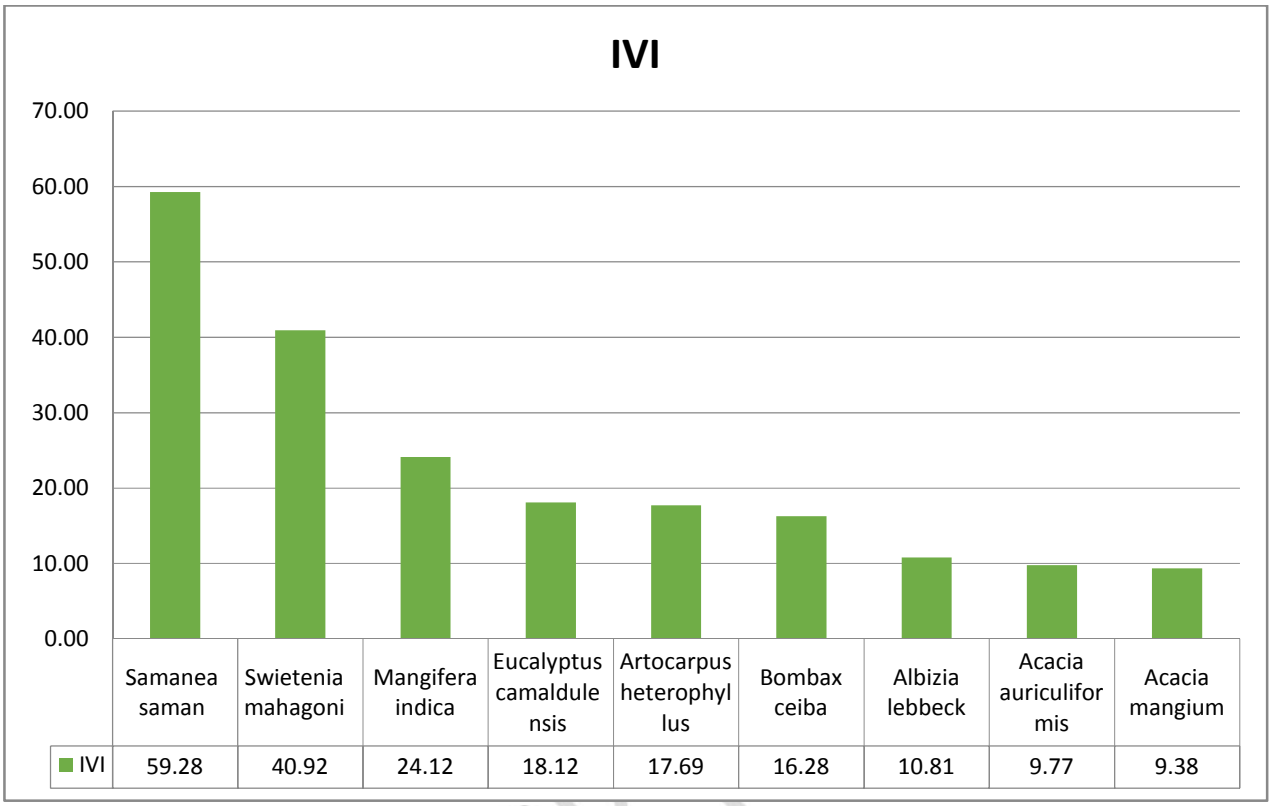

Figure 2 Important Value Index (IVI), distribution of the riparian tree species of Halda midstream.

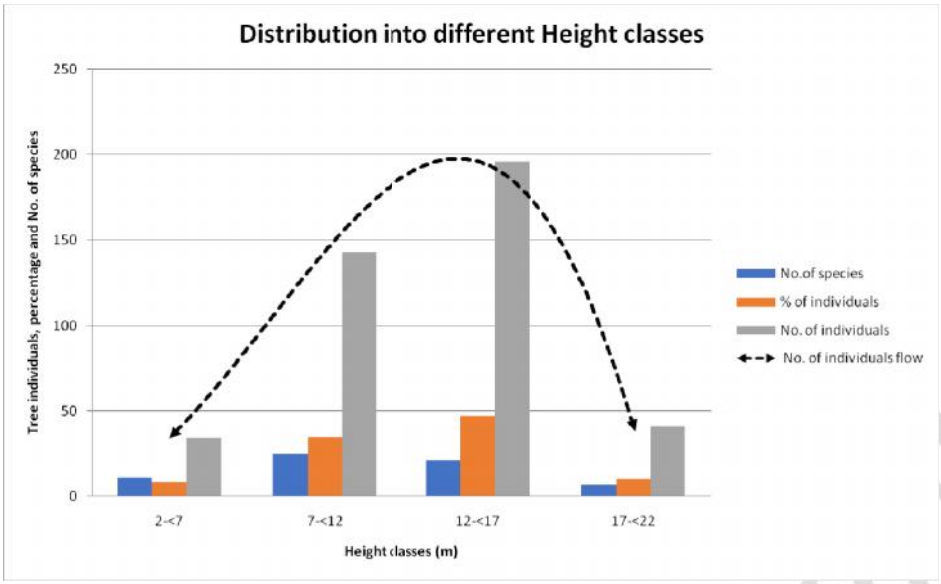

Figure 3 Vertical distribution of tree species and individuals into different height classes

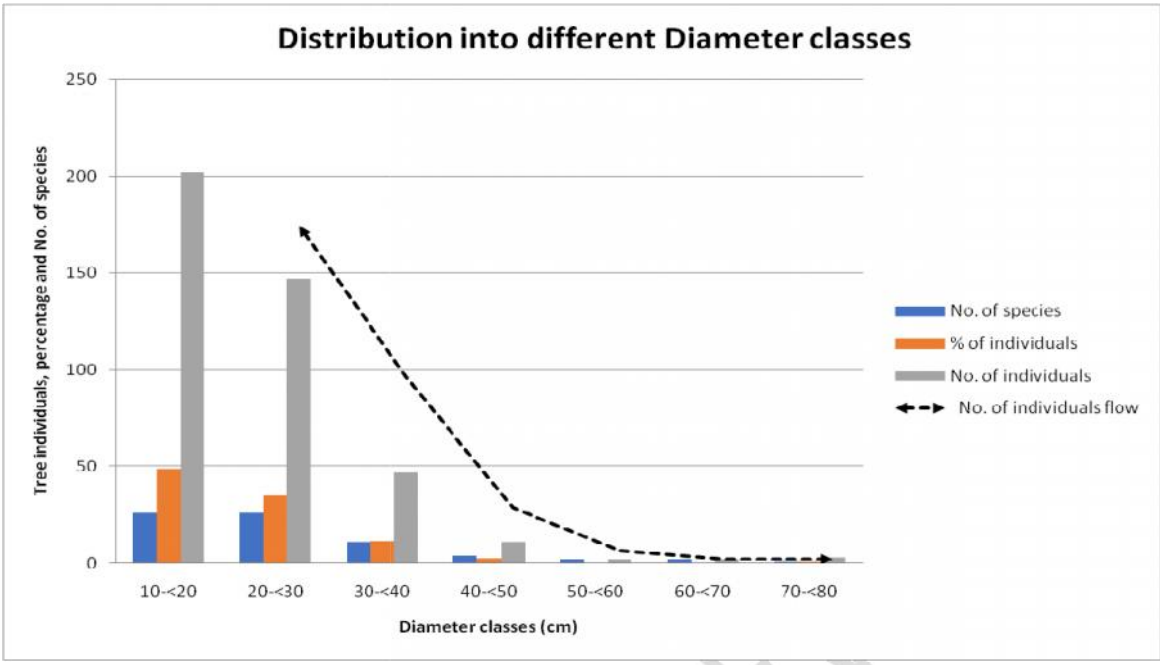

Figure 4 Distribution of tree species, number and percentage of tree individuals into different diameter classes

462 **Table 1 List of tree species recorded from the Halda riparian**

Sl. No.	Family	Sl. No.	Binomial name	Local name	No. of individual
1	Anacardiaceae	1	*Mangifera indica*	Aam	33
		2	*Spondias mombin*	Amra	1
		3	*Lannea coromandelica*	Jiol badi	8
2	Apocynaceae	1	*Alstonia scholaris*	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	*Trewia nudiflora*	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*	Kalo koroi	16
		6	*Albizia procera*	Sada koroi	6
		7	*Senna siamea*	Minjiri	1
		8	*Albizia odoratissima*	Tetua koroi	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

Sl. No.	Family	Sl. No.	Binomial name	Local name	No. of individual
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

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477 **Table 2 List of tree species with stem density per hectare recorded from Halda riparian**
478 **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	Kalo koroi	*Albizia lebbeck*	16	18.18
4	Tetua koroi	*Albizia odoratissima*	2	2.27
5	Sada koroi	*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	Teliya garjan	*Dipterocarpus turbinatus*	1	1.14
17	Jalpai	*Elaeocarpus serratus*	1	1.14
18	Mandar	*Erythrina variegata*	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	*Gmelina arborea*	5	5.68
22	Lombu	*Khaya anthotheca*	7	7.95
23	Jarul	*Lagerstroemia speciosa*	10	11.36
24	Jiol badi	*Lannea coromandelica*	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	*Senna siamea*	1	1.14
29	Amra	*Spondias mombin*	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

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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

503 **Table 4 Phytosociological attributes of the recorded tree species from the 22 quadrats**

504 **in Halda riparian**

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*	Kalo koroi	0.94	3.86	2.04	6.47	4.90	10.81
4	*Albizia odoratissima*	Tetua koroi	0.09	0.48	0.68	2.43	0.46	1.63
5	*Albizia procera*	Sada koroi	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*	Teliya garjan	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*	Jiol badi	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	*Neolamarckia cadamba*	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	*Spondias mombin*	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 jujuba*	Boroi	0.01	0.24	0.68	1.21	0.06	0.99

505 Note: RD = Relative density, RF = Relative Frequency, RA = Relative Abundance, RDo = Relative
506 Dominance, IVI = Importance Value Index

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518 **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- <7m	7- <12m	12- <17m	17- <22m	
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
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
Binomial name	**% distribution of tree species into different height(m) classes**				**Total**

	2- <7m	7- <12m	12- <17m	17- <22m	
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
Neolamarckia cadamba	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
Binomial name	**% distribution of tree species into different height(m) classes**				**Total**
	2- <7m	**7- <12m**	**12- <17m**	**17- <22m**	

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 jujuba	0.24	0.00	0.00	0.00	0.24
Total	8.21	34.54	47.34	9.90	100

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536 **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
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
Ficus benghalensis	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.48
Gmelina arborea	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	
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 jujuba	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

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