Original Research Article

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

Abstract

The study was conducted to assessed the tree species composition, structure and diversity of the midstream area of the Halda Rriver, Bangladesh. Twenty twootal number of 22 quadrats (20m × 20m in size) wereas 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. Include methodology before results - -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 was represented by maximum number of treewith nine species, (9) followed by Moraceae, Meliaceae and Anacardiaceae. Density, bBasal area and volume of the tree sspecies were 470.45 stem/ha, 19.09m²/ha and 139.42m³/ha, respectively. Among the tree species *Samanea saman* was found to be dominant, showing a 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 andas 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~~ playing ~~very~~ crucial roles in the development of any country. Any country's economy and development are greatly dependent on the ~~productions and~~ ecosystem services that rivers provide ~~a river~~ such as fresh water supply, fish production, transportation, waste assimilation etc., along with the 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 the Halda River in Chittagong, Bangladesh ~~its resources~~ need to be conserved. Indicate the importance of this river first before indicating problems. 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 ~~quarr~~quarrying for~~y~~ of sands etc. continue to threaten its existence (Dey 2017). Besides, the riverbank erosion, an increase of salinity in the river ~~now~~ threatens the livelihood of several thousand fishermen and fish 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).

Comment [MJ1]: Already indicated that industrial discharge is a problem above – duplication – remove this sentence

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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 H~~h~~alda ecosystem was also estimated (Akhter 2015). The conservation of Halda river in cooperation with river-dependent community was ~~als~~o investigated by ~~(~~Kabir et al. (2015). Studies were also done on the spawning of major Indian carp (Tsai et al. 1981), while ~~and~~ the biodiversity status of carps in the river ~~which~~ assessed via their distribution ~~of carps~~ and most important zones of spawning (Ferdous 2015). Bhuyan and Bakar (2017) looked at t~~T~~he sediment ~~analysis~~ and the heavy metal contamination in the water of the Halda R~~r~~iver ~~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)~~.

Comment [MJ3]: Recently is not 2014!

Despite of all these studies above mentioned ~~above~~, the tree species composition on the bank of the river which is the most important component of Halda R~~r~~iver ecosystem i~~was~~s 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~~investigation assessed 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.~~

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2. Materials and Methods

2.1 Description of the s~~S~~tudy 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 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). ~~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 resoureeful 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.

Comment [MJ4]: Is this statement still true for 2019? Be careful of using such very OLD information to indicate what is happening in 2019. – check the information to see if this still holds true.

Comment [MJ5]: This information is not necessary to understand the results! Present only information that is relevant to the results!

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.

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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 (~~Chaturved 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

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 (Margalef 1958).

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 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

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,*

227 *Areca catechu, Albizia lebbeck, Acacia auriculiformis, Acacia mangium,Bombax ceiba* for
228 meeting fruit, fuel, timber needs for family.

229

230 **3.2 Diversity Indices**

231 Different diversity indices, i.e Shannon-Wienner Diversity Index (H), Margalef 's richness
232 index (R), Simpon's Dominance Index (D), Pielou's Species Evenness Index (E) and
233 Menhinick's richness index(DI) were calculated to depict tree species diversity of the study
234 area (**Table 3**). Among these, 2.86 was found for Shannon-Wienners Diversity Index where
235 Simpson's Dominance Index was 0.91. Moreover, Margalef's Richness Index was calculated
236 as 5.81, Pielou's Species Evenness Index was 0.80 and Menhinick's richness index was 1.77.

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

240 The value of Shannon-Wienners Diversity Index 2.86 which generally indicates a relatively
241 diversity rich area as the value of this index range between 1.5 to 3.5 (Shannon & Weiner
242 1963c) but as Shannon-Wienners Diversity Index is used while comparing the diversity of
243 two different land areas, the value was found poorer comparing by Sithapahar reserve
244 forest(Nath et al., 2000) and Tankawati natural forest of Chittagong (South) Forest Division
245 (Motaleb & Hossain 2011) where the value is 2.98 and 3.25 respectively. The index is also
246 lower in comparison to Shanon-Wiener's diversity index of 4.449 in Dhudpukuria-
247 Dhopachori Wildlife Sanctuary (Hossain et al. 2013).

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

252 The Margalef's Richness Index (5.81) and Menhinick's richness index (1.77) which indicates
253 the number of species or richness of species along with Pielou's Species Evenness Index
254 (0.80) which ranges from (0-1) and which shows the relative abundance indicating the
255 riparian Halda midstream as a high diversity area.

256 **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- <50 cm, 50- <60 cm,60- <70cm 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 & Figure 4**). Only *Samanea saman* belongs to the highest dbh class 70- <80 cm.

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. Discussion

54. 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 vegetation~~s~~. 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.

Comment [MJ7]: A direct repetition of the Introduction, Aim, materials and methods and Results – remove all direct duplication – INSIGHT IN NEEDED!

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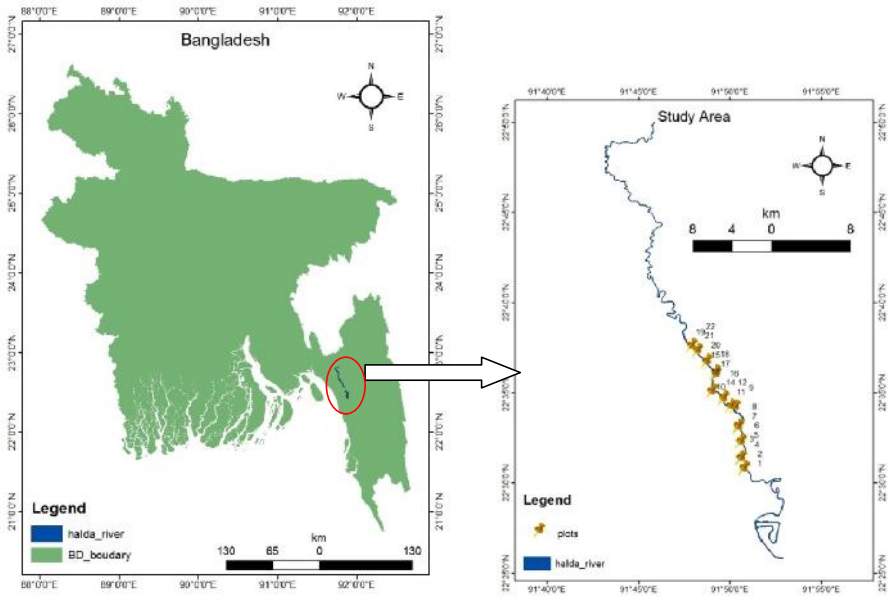

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402 **Figure 1** Map of the study area of Halda river

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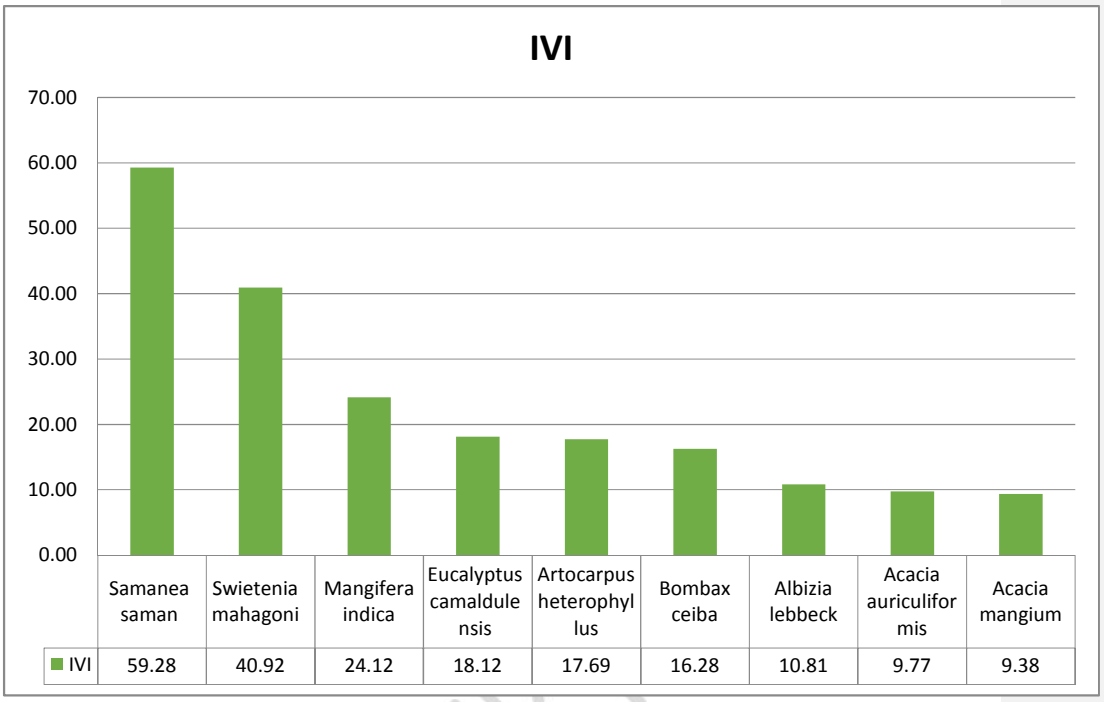

Figure 2 Important Value Index (IVI), distribution of the riparian tree species of Halda midstream.

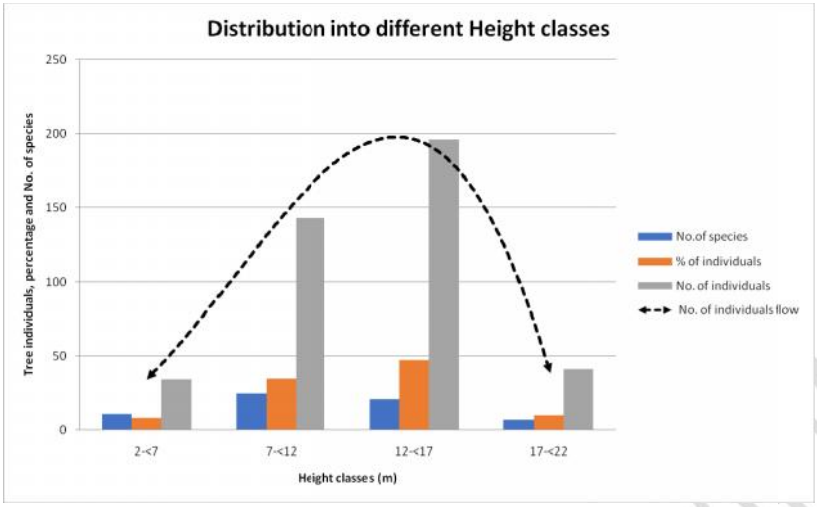

Figure 3 Vertical distribution of tree species and individuals into different height classes

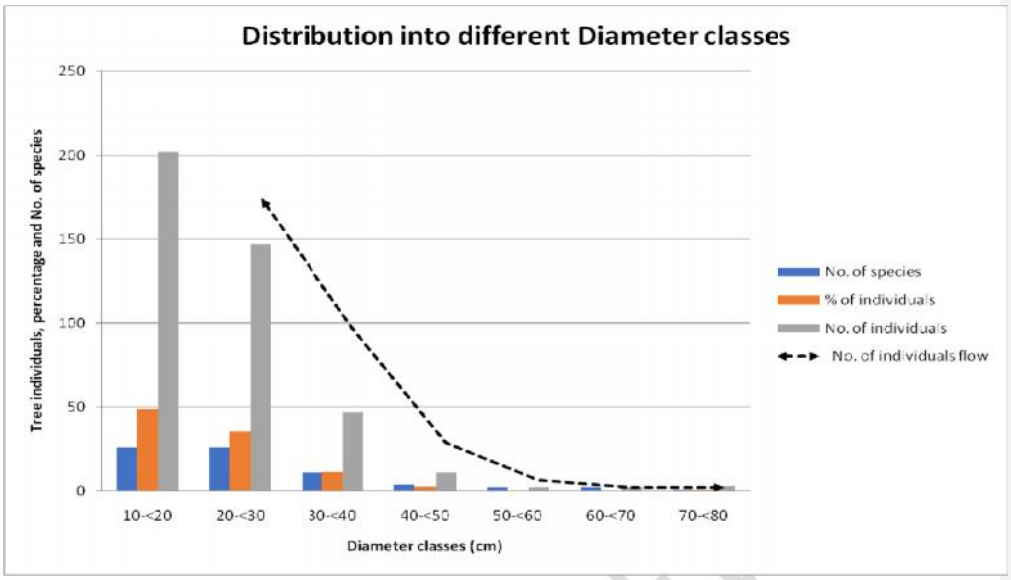

Figure 4 Distribution of tree species, number and percentage of tree individuals into different diameter classes