Bangladesh J. Plant Taxon. **30**(2): 263-275, 2023 (December) DOI: https://doi.org/10.3329/bjpt.v30i2.70502

TREE DIVERSITY, ABUNDANCE AND DOMINANCE IN THE LAKESIDE VEGETATION OF DHAKA CITY, BANGLADESH

EVANA AKTER AND MOHAMMAD ZASHIM UDDIN*

Department of Botany, University of Dhaka, Dhaka 1000, Bangladesh

Keywords: Tree diversity; Dominance; Lakeside vegetation; Dhaka city.

Abstract

The present article deals with evaluating tree diversity, abundance, and dominance in the urban lakeside vegetation of Dhaka city. Data were collected using systematic sampling methods along with the transect lines. Visitor's perceptions about existing tree diversity were also collected. A total of 2322 individuals under 118 tree species in 39 families were recorded from Dhanmondi, Hatirjheel and Gulshan lakeside vegetations. The origin analysis of tree species revealed that 39% are exotic and 61% are native. Among the tree species, the five most abundant are *Swietenia mahagoni*, *Mangifera indica*, *Cocos nucifera*, *Khaya anthotheca* and *Delonix regia*. In these abundant tree species, three are exotic, such as *Swietenia mahagoni, Khaya anthotheca,* and *Delonix regia*, and the rest are native. According to the importance value index, the most five dominant tree species are *Swietenia mahagoni*, *Samanea saman*, *Cocos nucifera*, *Mangifera indica*, and *Delonix regia*. Likewise, among the top five dominant tree species, three are exotic, such as *Swietenia mahagoni, Sananea saman,* and *Delonix regia; the* rest are native. The maximum number of tree species in the study areas are ornamental (25%), followed by medicinal (23%), fruit-bearing (22%), timber-producing (19%), and wildlife-supporting (11%). The maximum value of the Shannon diversity index was found in Dhanmondi (3.78), followed by Gulshan (3.41), and Hatirjheel (3.34). According to visitors' perceptions, 85% of visitors favored positive actions regarding different management issues for lakeside tree diversity to enhance ecosystem services. A number of threats were identified for tree diversity in the study areas and suggested a number of recommendations for the management of tree diversity in three lakesides of vegetation (Dhanmondi, Hatirjheel, and Gulshan) to improve ecosystem services in the future.

Introduction

The article explored existing tree species diversity, abundance, dominance, uses and their origins in the lakeside vegetation of Dhaka city. Data on these aspects of trees are very much desirable for the sustainable management of urban environment. Tree diversity plays an important role in providing ecosystem services to urban communities, environment, and as well as biodiversity as cited by many scientists of the world (Singh *et al*., 2018; Jim and Liu, 2001; Zhang and Jim, 2014; Onyekwelu *et al*., 2008; Rahman *et al*., 2011, 2018; Vila- Ruiz *et al*., 2014; Clarke and Jenerette, 2015; Su *et al*., 2021; Tordoni *et al*., 2017; Cay and Asilioglu, 2014; Uddin and Hassan, 2016; Pasha *et al*., 2021; Uddin *et al.*, 2021).

Currently, urban plant diversity is very popular topic in scientific research of many countries of the world as mention earlier above works but in Bangladesh such research is in the initial stage. Most noteworthy works on the plant diversity of Dhaka city are included Datta and Mitra (1953), Alam (1967), Hossain (1966), Hossain (2006), Huq and Begum (1984), Hussain (1965), Khan

*Corresponding author, E-mail: zashim01@gmail.com

and Huq (1981), Rahman (1966), Zeauddin (1967), Hossain and Uddin (2011), Uddin and Hassan (2016) and Uddin *et al.* (2019, 2021). All this research works were covered mostly on the inventory of plant diversity of Dhaka city, list of plant species under families and one was on the plant diversity of road dividers. But no works are available on the tree diversity of lakeside vegetation of Dhaka city. Lakeside vegetation in Dhaka city has been played an important role to ensure congenial environment of urban life. The areas now used mostly for amusement, morning and evening walks, leisure and also for nature learning thus cultural services. If manage properly, the areas could be a hub for biodiversity conservation and ecosystem services to urban communities. In the present study an attempt was taken to achieve the following objectives: to determine diversity of tree species, abundance, dominance, uses and origins; to find the threats to tree diversity; and to find perceptions from visitors for the better management of tree diversity in three urban lakeside vegetation of Dhaka city.

Materials and Methods

Study area

Three lakesides, including Dhanmondi, Hatirjheel, and Gulshan (Fig. 1), were selected for the data collection. Dhanmondi Lake has a surface area of 37.37 ha, a length of 3 km, a width of 35 to 100 m, and a maximum depth of 4.77 m (Parvin *et al*., 2019). It is only connected to a culvert, the only outlet that aids in removing extra floodwater brought on by significant precipitation. The mean depth of Hatirjheel Lake is 2 m, with a total area of 32.70 ha. The mean depth of Gulshan Lake is 2.50 m, and its surface area is 58.86 ha. These three lakeside vegetations have been managed by both the Dhaka North and South City Corporations.

Filling sand, clay, and sand mixtures make up the majority of the soils in Dhaka city. Occasionally, an extra clay layer has been noticed. According to Ansary *et al.*, (2015), the original ground is primarily composed of clay layers, with a sand layer situated beneath them. The climate of Dhaka is tropical, hot, humid, and rainy. A distinct monsoonal season occurs in the city, with an average yearly temperature of 27.5 °C. About 2000 mm of rain fall on the city each year, with over 80% of that falling between June and September during the monsoon season (Dewan and Yamaguchi, 2009). In addition to its tropical vegetation, Dhaka's topography is flat and at sea level, with damp soils that make it vulnerable to flooding during monsoon seasons due to cyclones and excessive rains. (Hough, 2004). Vegetation of Dhaka now planted type with mostly exotic plants (Uddin *et al*., 2021). Plantation activities has regulary been conducted by both Dhaka north and Dhaka south city corporation. The most common plant species are *Samanea saman, Swietenia mahagony*, *Polyalthia longifolia*, *Mimusops elengi*, *Acacia auriculiformis*, *Albizia richardiana*, *Eucalyptus camaldulensis*, *Leucaena leucocephala*, *Mangifera indica* and *Artocarpus heterophyllus*. Abundance of exotic plant species higher than indigenous plant species (Uddin *et al*., 2021).

Methods of the study

A total of 12 field trips was made to the study areas in Dhanmondi, Hatirjheel and Gulshan lakeside vegetations during June 2022 to May 2023. The study was conducted using a systematic sampling method (Peet *et al.*, 1998 and Stohlgren *et al*., 1998). By this way, a total number of 274 quadrats of 10m×10m were taken from three lakeside vegetations (Oosting, 1956). The number of quadrates in study area was determined using species area curve (Goldsmith and Harrison, 1976). In each quadrat, tree species were also identified, counted individual number and recorded Diameter at Breast Height (DBH). To determine the dominant tree species, Importance Value Index (IVI) were calculated using biostatistical formulas (Krebs, 1989). Species diversity was

determined using Shannon-Weiner diversity index (Shannon, 1948), Simpson diversity index (Simpson, 1949), Margalef index (Margalef, 1957) and Pielu index (Pielou, 1981). Exotic tree species were determined comparing with reports of Pasha and Hossain (2004).

Most of the identification of tree species was done by experts at field site. In case of confusions in identity, plant samples were taken and brought to the Plant Taxonomy Laboratory of the Department of Botany, University of Dhaka and processed using standard herbarium techniques (Hyland, 1972). And also took color images of plant specimens using a digital camera for aiding in identification. The plant samples were identified up to the species by consulting different literature (Datta and Mitra, 1953; Khan and Huq, 1981; Uddin and Hassan, 2016; Uddin *et al.*, 2021; Siddiqui *et al*., 2007; Ahmed *et al*., 2008-2009) and also comparing with herbarium specimens preserved in Dhaka University Salar Khan Herbarium (DUSH).

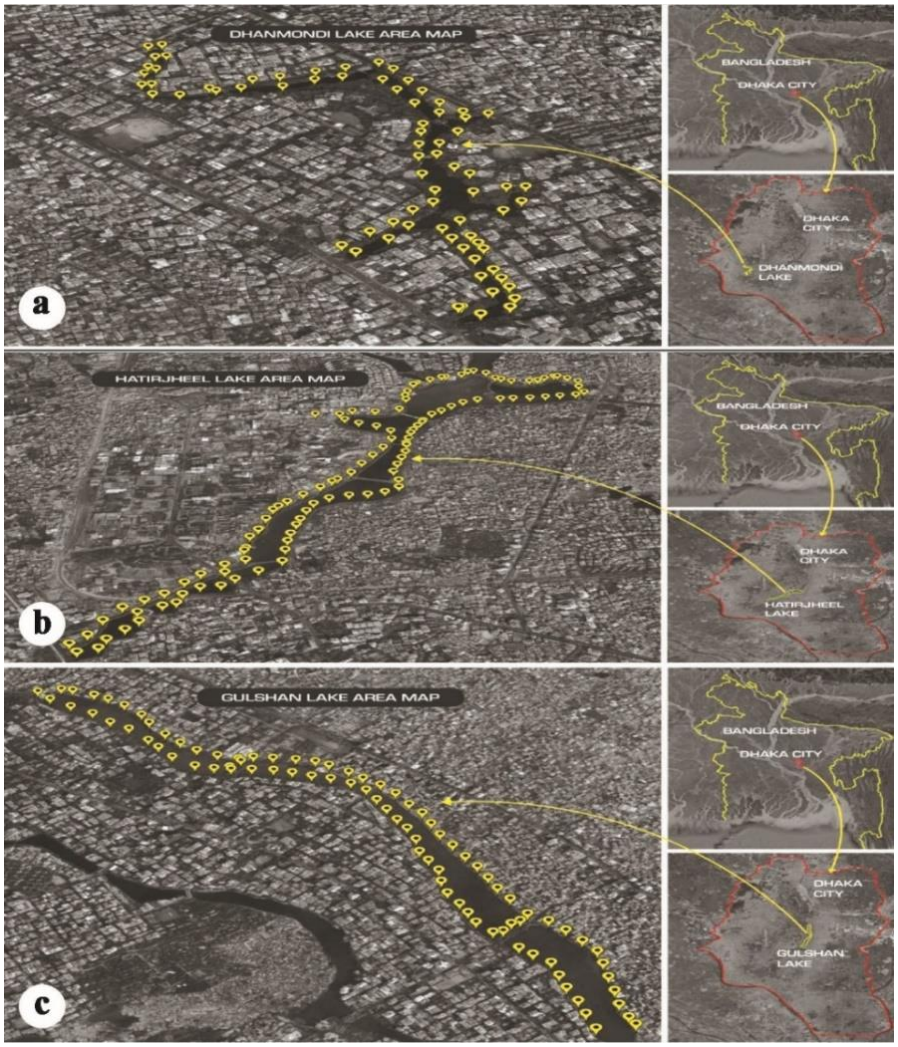

Fig. 1. Map of the study area showing the place of quadrats a. Dhanmondi Lakeside, b. Hatirjheel Lakeside and c. Gulshan Lakeside (Source: Google earth).

To know the perceptions of visitors, a total of 80 informants were interviewed using structured questionnaire in the study sites (Alexiades, 1996). The ages of informants ranged from 18 to 78 years. The education backgrounds of the informants ranged from under degree to M.Sc. and MBA degrees. They were primarily as housewives, shopkeepers, corporates and government offcials.

Results and Discussion

Inventory of tree species diversity

The study recorded a total of 2322 individuals under 118 species from the Dhanmondi, Hatirjheel, and Gulshan lakeside vegetations of Dhaka city. These species were assigned to 39 families. For each species, the scientific name, family, abundance, origin status, and usefulness were determined and presented in Table 1. Plant species are not equally distributed in the family. In this case, eight families account for 53% of the species, while another 31 families account for 47%. Arecaceae is the most dominant family, followed by Fabaceae, Myrtaceae, Moraceae, Meliaceae, Anacardiaceae, Caesalpiniaceae, Combretaceae, and Rubiaceae (Fig. 1). Based on their ecosystem services, the plant species found in the overall study sites were separated into a number of use categories. The majority of tree species fall into the category of ornamental species, followed by fruit-bearing, timber-producing, medicinal, and wildlife-supporting species (Fig. 2). Most of the tree species that are planted in the laksides are decorative plants, which serve purely aesthetic purposes rather than serving an ecological or everyday social requirement or providing other ecosystem services. This finding demonstrates that the study area's vegetation only provides a limited number of ecosystem services; as a result, modifications are necessary to increase these services' availability and increase the community's ability to enjoy them. Uddin *et al.* (2021) reported 77 tree species from the road dividers of Dhaka city. Again, Uddin and Hassan (2016) reported 157 tree species from the Dhaka University campus. If compared to the present number of tree species in lakeside vegetation with road dividers and the Dhaka University campus, the diversity of tree species indicates the moderate richness of lakeside vegetation in Dhaka.

Table 1. Tree species diversity in the urban lakeside vegetation of Dhaka city.

Species name	Common name	Family	Presence in site	Abun -dance	Origin	Use
Acacia auriculiformis A. Cunn. *ex* Benth.	Akashmoni	Mimosaceae	D,H,G	6	E	T
A. mangium Willd.	Belijum	Mimosaceae	H	2	E	T
Adenanthera pavonina L.	Ranjana	Fabaceae	D,G	3	N	M
Aegle marmelos (L.) Corr.	Bel	Rutaceae	D,H,G	7	N	F
Albizia lebbeck (L.) Benth.	Shilkoroi	Mimosaceae	D	6	N	T
A. procera (Roxb.) Benth.	Sada koroi	Mimosaceae	D,H,G	8	N	T,WS
A. richardiana (Voigt) King & Prain	Gogonshirish	Fabaceae	D,H,G	33	E	T, WS
Alstonia scholaris (L.) R.Br	Chatim	Apocynaceae	D,H,G	6	N	M, T, WS
Anisoptera scaphula (Roxb.) Kurz	Boilam	Dipterocarpaceae	H	1	N	T
Annona reticulata L.	Ata	Annonaceae	D,H,G	10	E	F
A. squamosa L.	Ata	Annonaceae	G	1	N	F, T, WS
Araucaria heterophylla (Salisb.) Franco	Chrismass tree	Araucariaceae	G	2	E	O
Areca catechu L.	Supari	Arecaceae	D,G	14	E	F
Artocarpus chama Buch.-Ham.	Chapalish	Moraceae	D	10	N	T
A. heterophyllus Lam.	Kathal	Moraceae	D,H,G	73	N	F, T, V, WS
A. lacucha Buch.-Ham.	Deua	Moraceae	D,G	5	N	F, T, WS
Averrhoa bilimbi L.	Bilimbi	Avverhoaceae	G	1	E	F

Species name	Common name	Family	Presence in site	Abun-dance	Origin	Use
A. carambola L.	Kamranga	Avverhoaceae	D,H,G	9	E	F
Azadirachta indica A. Juss.	Neem	Meliaceae	D,H,G	25	N	M, T, WS
Barringtonia acutangula (L.) Gaertn.	Hijol	Lecythidaceae	D,H,G	23	N	T
Bauhinia purpurea L.	Debkanchon	Caesalpiniaceae	D,G	3	N	M, O
B. variegata L.	Rakta kanchan	Caesalpiniaceae	D,H	14	N	M, O,T
Bombax ceiba L.	Shimul tula	Bombaceae	D,H,G	24	N	O, WS
Borassus flabellifer L.	Tal	Arecaceae	D,H,G	66	N	WS, F, M,T
Bouea oppositifolia (Roxb.) Adelb.	Mailam	Anacardiaceae	H	1	N	F
*Butea monosperma (*Lam.) Taub.	Polash	Fabaceae	D,H,G	17	N	M, O
Calliandra haematocephala Hassk.	Powder puff	Fabaceae	D	1	E	O
Callistemon citrinus (Curtis) Skeels	Lal bottle brush	Myrtaceae	H	2	E	M, O
Callistemon pallidus (Bonpl.) DC.	Sada bottle brush	Myrtaceae	H	2	E	O
Caryota urens L.	Chaur	Arecaceae	D,G	11	N	O
Cassia grandis L.f.	Lal sonail	Caesalpiniaceae	D,H,G	14	N	M
B. fistula L.	Sonalu	Caesalpiniaceae	D,H,G	17	N	O, M
C. nodosa Roxb.	Java sonail	Caesalpiniaceae	D,H	3	N	O
A. renigera Benth.	Lal sonail	Caesalpiniaceae	H	1	E	M
Casuarina equisetifolia L.	Jhau	Casuarinaceae	D,H	35	E	T
Ceiba pentandra (L.) Gaertn.	Shet shimul	Bombacaceae	D,H	13	N	WS
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	Tejpata	Lauraceae	D	1	N	M
C. verum J.Presl	Daruchini	Lauraceae	D	1	E	M
Cocos nucifera L.	Narikel	Arecaceae	D.H.G	164	N	F
Cordia dichotoma G. Forst.	Bohola	Boraginaceae	D,H	2	N	Gu, M
Crateva nurvala Buch.-Ham	Barun	Capparaceae	G	1	N	M
Cycas revoluta Thunb.	Cycas	Cycadaceae	H	1	E	O
Dalbergia sissoo DC.	Shishu	Fabaceae	D,H,G	7	E	T
Delonix regia (Bojer) Raf.	Krishnachura	Caesalpiniaceae	D,H,G	95	E	O, M
Dillenia indica L.	Chalta	Dilleniaceae	D,H,G	5	N	F
Diospyros blancoi A. DC.	Bilati Gaab	Ebenaceae	D,H,G	5	E	F
Diospyros cordifolia Roxb.	Tomal	Clusiaceae	D	1	N	M
C. malabarica (Desr.) Kostel.	Deshi gab	Ebenaceae	D,H	3	N	F
Dipterocarpus turbinatus C.F.Gaertn	Gorjon	Dipterocarpaceae	H	1	N	T
Dypsis lutescens (H.Wendl.) Beentje & J. Dransf.	Areca palm	Arecaceae	D,G	20	E	O, WS
Elaeocarpus floribundus Blume	Jolpai	Elaeocarpaceae	D,H,G	4	N	F
Erythrina variegata L.	Mandar	Fabaceae	D	1	N	WS
Eucalyptus camaldulensis Dehnh.	Eucalyptus	Myrtaceae	D,G	8	E	T, M
Ficus benghalensis L.	Lal bot	Moraceae	D,H,G	35	N	WS, T
D. benjamina L.	Jhir bot	Moraceae	D,H,G	15	N	WS
E. elastica Roxb. *ex* Hornem.	Rubber bot	Moraceae	D,H,G	3	E	WS
F. hispida L.f.	Kakdumur	Moraceae	D,H,G	17	N	WS
F. racemosa L.	Dumur	Moraceae	D,G	9	N	WS
F. religiosa L	Ashwath	Moraceae	G	1	N	WS, T
F. rumphii Blume	Pakur	Moraceae	D,H,G	7	N	M, T, WS
Hopea odorata Roxb.	Telshur	Dipterocarpaceae	H	9	N	T
Hyophorbe lagenicaulis (L.H. Bailey) H.E. Moore	Bottle palm	Arecaceae	D,H	32	E	O

Species name	Common name	Family	Presence in site	Abun -dance	Origin	Use
Jacaranda mimosifolia D. Don	Jacaranda	Bignoniaceae	D,H	3	E	O
Khaya anthotheca (Welw.) C. DC.	Lombu	Meliaceae	D,H,G	146	E	T
Lagerstroemia speciosa (L.) Pers.	Jarul	Lythraceae	D,H,G	45	N	O
Lannea coromandelica (Houtt.) Merr.	Jiga	Anacardiaceae	D	2	N	WS, Fn, Gu
Lepisanthes rubiginosa (Roxb.) Leenh.	Horinhara	Sapindaceae	G	1	N	F, Fw
Leucaena leucocephala (Lam.) de Wit	Epil-epil	Fabaceae	D,H,G	42	E	T
Litchi chinensis Sonn.	Lichu	Sapindaceae	D,H,G	6	E	F
Litseaglutinosa (Lour.) C.B. Rob	Menda	Lauraceae	D,H,G	11	N	M
Livistona chinensis (Jacq.) R.Br. *ex* Mart.	China palm	Arecaceae	D,G	2	E	O
Macaranga peltata (Roxb.) Muell.Arg.	Chandana	Euphorbiaceae	G	1	N	O
Madhuca longifolia (J.Koenig *ex* L.) J.F.Macbr.	Mohua	Sapotaceae	D,H,G	6	N	F, M, WS
Mallotus nudiflorus (L.) Kulju &Welzen	Pitali	Euphorbiaceae	G	2	N	O
Mangifera indica L.	Aam	Anacardiaceae	D,H,G	209	N	F, M, T, WS
Manilkara zapota (L.) P. Royen	Sofeda	Sapotaceae	D,G	5	E	F
Melia azedarach L.	Goranim	Meliaceae	D,G	2	E	T, WS
Memecylon umbellatum Burm. f.	Anjan	Melastomataceae	D	3	E	O
Michelia champaca L.	Swarna chapa	Magnoliaceae	D,H	4	N	O
Millettia ovalifolia Kurz	Monihar	Fabaceae	H	1	E	M
Mimusops elengi L.	Bokul	Sapindaceae	D,H,G	67	E	O
Moringa oleifera Lam.	Sajna	Moringaceae	H,G	21	E	M
Neolamarckia cadamba (Roxb.) Bosser	Cadam	Rubiaceae	D,H,G	47	N	T
Peltophorum pterocarpum (DC.) Backer *ex* K. Heyne	Konokchura	Caesalpiniaceae	D,H,G	18	E	O
Phoenix sylvestris (L.) Roxb.	Khejur	Arecaceae	D,H,G	21	N	F
Phyllanthus emblica L.	Amloki	Euphorbiaceae	D,H,G	8	N	M
P. acidus (L.) Skeels	Aorboroi	Phyllanthaceae	H	1	N	M
Pithecellobium dulce (Roxb.) Benth.	Khoiababla	Fabaceae	D	1	E	M
Plumeria alba L.	Katgolap	Apocynaceae	D,H,G	4	E	O
Polyalthia longifolia (Sonn.) Thwaites	Debdaru	Annonaceae	D,H,G	67	E	O
Pterocarpus indicus Willd.	Padauk	Fabaceae	D	1	E	O
Pterygota alata (Roxb.) R.Br.	Buddha narikel	Sterculiaceae	D	1	N	M, T
Putranjiva roxburghii Wall.	Putrojib	Euphorbiaceae	D,G	5	N	M
Samanea saman (Jacq.) Merr.	Rain tree	Mimosaceae	D,H,G	91	E	T
Sapindus mukorossi Gaertn.	Ritha	Sapindaceae	H	1	N	T
Saraca asoca (Roxb.) Willd.	Ashok	Fabaceae	D,G	5	N	O
Senna siamea (Lam.) H.S. Irwin & Barneby	Minjiri	Caesalpiniaceae	D,H	7	E	Fw, O
Spondias pinnata (L. f.) Kurz	Amra	Anacardiaceae	D,H,G	10	N	F
Sterculia foetida L.	Basket badam	Sterculiaceae	H,G	5	N	T
S. villosa Roxb.	Udal	Sterculiaceae	H	6	N	M
Streblus asper Lour.	Sheora	Moraceae	D,G	5	N	M
Swietenia macrophylla King	Boro Mehegoni	Meliaceae	D,G	11	E	T
S. mahagoni (L.) Jacq.	Mehegoni	Meliaceae	D,H,G	326	E	T
Syzygium cumini (L.) Skeels	Jam	Myrtaceae	D,H,G	28	N	F

Species name	Common name	Family	Presence in site	Abun -dance	Origin	Use
S. jambos (L.) Alston	Golap- jam	Myrtaceae	D	3	E	F
S. samarangense (Blume) Merr. & L.M. Perry	Jamrul	Myrtaceae	D,G	5	E	F
S. fruticosum DC.	Vuti jam	Myrtaceae	H	2	N	F, M, T, WS
Tamarindus indica L.	Tetul	Caesalpiniaceae	D,H,G	12	N	M
Tectona grandis L.f.	Segun	Verbenaceae	D,H	9	E	T
Terminalia arjuna (Roxb. *ex* DC.) Wight & Arn.	Arjun	Combretaceae	D,H,G	13	N	M
T. bellirica (Gaertn.) Roxb.	Bohera	Combretaceae	D,H,G	11	N	M, F,T,WS
T. catappa L.	Kathbadam	Combretaceae	D,H,G	46	E	F,M, O, WS
T. chebula Retz.	Horitoki	Combretaceae	D,H	5	N	M
T. mantaly H.Perrier	Nakachua	Combretaceae	G	1	E	M
Trema orientalis (L.) Blume	Jibon	Ulmaceae	D,H,G	19	N	WS
Wrightia coccinea (Roxb. *ex* Hornem.) Sims	Palam	Apocynaceae	D,H	8	N	O
Xanthoxylum rhetsa (Roxb.) DC.	Bajna	Rutaceae	D,H	2	N	M, Oy
Ziziphus mauritiana Lam.	Boroi	Rhamnaceae	D,H,G	21	N	F, M,WS

Presence in site D= Dhanmondi, H=Hatirjheel, G=Gulshan; (Native or Exotic: N= Native, E= Exotic origin; Uses: T= Timber, M= Medicinal, F= Fruit, O= Ornamental, WS= Wildlife Supporting, Oy = Oil yielding, Fw= Fuel wood, Gu = Gum, Fn = Fence.

Abundant tree species

According to analysis, among the 118 tree species in the research area, the top 15 most abundant tree species were *Swietenia mahagoni*, followed by *Mangifera indica*, *Cocos nucifera*, *Khaya anthotheca*, *Delonix regia*, *Samanea saman*, *Artocarpus heterophyllus*, *Polyalthia longifolia*, *Mimusops elengi*, *Borassus flabellifer*, *Neolamarckia cadamba*, *Terminalia catappa*, *Lagerstroemia speciosa*, *Ficus benghalensis*, and *Albizia richardiana* (Fig. 3). These tree species predominate in urban areas due to the greater availability of their seedlings in nurseries, the scarcity of native tree sprouts, the promotion of urban greeing, the potential neglect of native plant conservation issues, or the lack of significant consideration given to plant taxonomists' knowledge when planting. The widespread distribution of these plant species around the city does not accurately represent the rich natural history of our vegetation of the country.

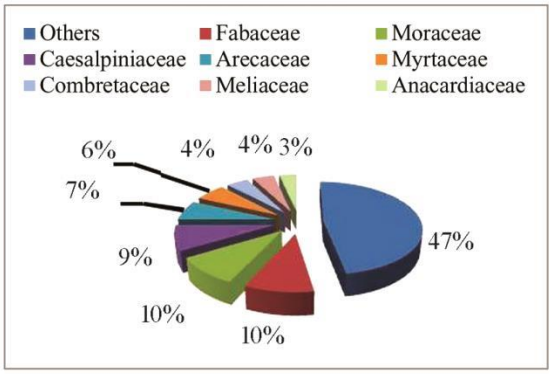

Fig. 1. Dominant tree families of three study sites.

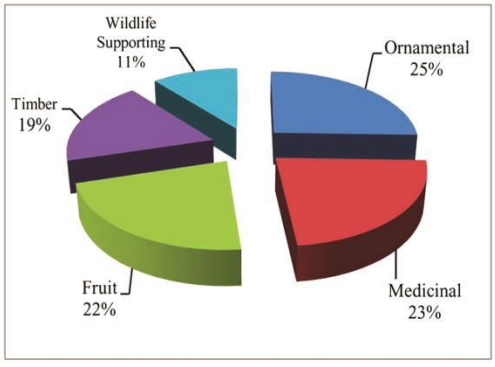

Fig. 2. Tree species of different use groups.

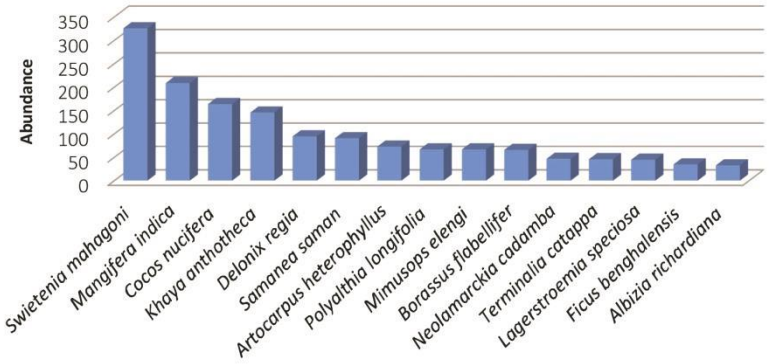

Fig. 3. Top 15 abundant trees in three study sites

Dominant tree species

The Important Value Index was generated to identify the dominant tree species on lakeside vegetations in Dhanmondi, Hatirjheel, and Gulshan areas of Dhaka city. According to the findings, *Swietenia mahagoni* is the top dominant tree species, followed by *Samanea saman*, *Cocos nucifera*, *Mangifera indica*, and *Delonix regia*. Additionally, these tree species also displayed higher relative densities, relative frequencies, and relative abundances. Among the top 15 dominant tree species, seven were native and eight were exotic (Table 2). According to Uddin *et al*. (2021), the top dominant tree species on the road dividers of Dhaka city was *Mimusops elengi*, whereas in the present research, the top dominant tree species in the lakeside vegetation was *Swietenia mahagoni*. Because of aesthetic reasons, the maximum *Mimusops elengi* sampling was planted on road dividers. On the other hand, for the creation of green vegetation and timber value, *Swietenia mahagoni* sampling was planted maximum in the lakeside.

Table 2. Important value index of tree species in the study area.

Species Name	Origin	Abundance	Relative density	Relative frequency	Relative abundance	Important value Index
Swietenia mahagoni (L.) Jacq.	Exotic	326	14.03962	8.7591241	11.555305	34.354049
Samanea saman (Jacq.) Merr.	Exotic	91	3.9190351	4.047777	18.944149	26.910961
Cocos nucifera L.	Native	164	7.0628765	4.910418	10.909083	22.882377
Mangifera indica L.	Native	209	9.0008609	8.4936961	4.5717796	22.066337
Delonix regia (Bojer) Raf.	Exotic	95	4.0913004	3.98142	6.9833417	15.056062
Khaya anthotheca (Welw.) C.DC.	Exotic	146	6.2876827	4.180491	3.6528531	14.121027
Borassus flabellifer L.	Native	66	2.8423771	4.246848	5.5989169	12.688142
Artocarpus heterophyllus Lam.	Native	73	3.1438414	3.782349	1.3185651	8.2447555
Neolamarckia cadamba (Roxb.) Bosser	Native	47	2.024117	2.322495	2.9506029	7.2972149
Polyalthia longifolia (Sonn.) Thwaites	Exotic	67	2.8854434	1.99071	1.9156007	6.7917541
Mimusops elengi L.	Exotic	67	2.8854434	2.853351	0.8874278	6.6262223
Ficus benghalensis L.	Native	35	1.5073212	2.189781	2.5219422	6.2190444
Terminalia catappa L.	Exotic	46	1.9810507	2.455209	1.4054341	5.8416938
Albizia richardiana (Voigt) King & Prain	Exotic	33	1.4211886	1.526211	1.8813703	4.8287699
Lagerstroemia speciosa (L.) Pers.	Native	45	1.9379844	1.99071	0.7932813	4.7219757

Tree species diversity

In the present study, Shannon Index (H) values for tree species diversity of three lakeside vegetations ranged from 3.78 to 3.34; Simpson's Diversity Index values ranged from 0.96 to 0.94; Margalef Index values ranged from 13.86 to 11.89; and Pielou's Evenness values ranged from 1 to 0.88 (Table 3). Among the diversity index values, Dhanmondi Lakeside showed higher value than the other two lakes. This is because Dhanmondi Lake developed earlier than Gulshan and Hatirjheel, and plantation activities and time were much longer than on the other two sides. There was also the recent plantion of many tree species with roughly equal numbers of individuals in Dhanondi lakeside. Gulshan and Hatirjheel Lakeside developed after Dhanmondi and were planted with the maximum number of individuals of a few tree species; that's the lowest Shannon, Simpson's, Margalef, and Pielou's evenness value. Although it was initially created in the context of information theory (Shannon, 1948), the diversity measure (represented by H) was later incorporated in the studies on species diversity (Margalef, 1957). Shannon's H provides a richer picture of an ecosystem's diversity than a simple count of species since it takes into account the proportion of each species in the environment under study (Konopiski, 2020). The index can distinguish between places where a single or a small number of dominant species predominate and those where each species has a comparable contribution to the overall plant diversity when the number of species in two locations is equal (Margalef, 1957). According to Uddin *et al*., (2021), the Shannon index value for the trees on the road dividers in Dhaka city was calculated at 3.17. The present value of the Shannon index for the trees in lakeside vegetation almost complied with the value of road dividers.

Table 3. Comparative diversity index values of tree species among the three lakesides.

Site name	Number of species	Number of individuals	Shannon-Weiner Diversity Index	Simpson's Diversity Index	Margalef Index of Species Richness	Pielou's Measure of Evenness value
Dhanmondi Lakeside	93	763	3.78	0.96	13.86	1
Hatirjheel Lakeside	83	988	3.34	0.94	11.89	0.88
Gulshan Lakeside	77	571	3.41	0.94	11.97	0.90

Since urbanization is a continuing global issue that is increasing every year, urban ecology is quickly becoming a focus of scientific study. Any information on the urban ecology is pertinent because most general and in-depth knowledge on urban biodiversity and ecological processes relates to cities and towns.

Exotic tree species

The current study has made an effort to determine the origin of the reported tree species diversity. The result revealed that 39% of recorded tree species are exotic whereas 61% are indigenous or native (Table 1). Due to factors like the accessibility of seedlings during plantation and/or a lack of taxonomic expertise during the species selection process, there may be a rise in the incidence of exotic tree species. Contractors typically handle plantation programs. Unfortunately, they cannot distinguish between native and exotic plant species. Some exotic species, such as *Swietenia mahagoni*, *Samanea saman*, *Delonix regia*, *Khaya anthotheca*,

Polyalthia longifolia, *Mimusops elengi*, *Terminalia catappa* and *Albizia richardiana* were the most dominant tree species in three study sites. Other exotic tree species that have been planted in urban lakeside areas are as follows: *Leucaena leucocephala*, *Hyophorbe lagenicaulis*, *Peltophorum pterocarpum*, *Acacia auriculiformis*, *Moringa oleifera*, *Dalbergia sissoo*, *Pterocarpus indicus*, *Swietenia macrophylla*, and *Ceiba pentandra*. The findings reveal that exotic tree species outnumber native tree species, which is surprising given that exotic tree species made up the majority of vegetations. Dhanmondi lakeside has nine exotic tree species, Hatirjheel Lakeside has seven, and Gulshan lakeside has nine exotic tree species out of the 15 most abundant tree species in each study area. *Peltophorum pterocarpum*, *Eucalyptus camaldulensis*, *Acacia auriculiformis*, *Terminalia catappa*, and *Dalbergia sissoo* were among the exotic species. These tree species are all easily snapped and have soft wood. Despite the aesthetic value of some of these plant species are typically not particularly favorable to animal diversity and can be a major risk during natural catastrophes in the densely populated metropolis of Dhaka (Uddin *et al*., 2021).

Visitor's perception

For the management issue of visitors in the three-lakeside vegetation, a number of structured questions were asked to 80 visitors based on the present findings of the tree diversity analysis. In the initial question on the promotion of tree diversity in lakeside vegetation, 91% of the informants gave positive responses to promote tree diversity, while only 9% gave negative responses. In the case of dominant exotic tree species, 85% of participants opposed it, while only 15% supported it. In the case of native tree species, most people preferred native tree species in their beloved city, Dhaka, but few people preferred exotic species for aesthetic reasons only. In the case of the utility of tree species, a total of 86% of interviewees chose an evenly distribution of all purposeful tree species, whereas 14% of the population just desired the plantation for its aesthetic appeal. In the case of expert knowledge during plantation management, all positions require experts' guidance during plantation. The existing vegetation scenario does not represent professional opinion; all informants made it quite obvious. Therefore, it is crucial to seek the advice of experts while managing urban vegetation. The last question was about restoring the floral heritage of Dhaka city by planting the once-existing plants. Total 85% of the participants responded favorably, 8% negatively, and 7% confusedly, debating whether or not something would be feasible.

Conclusion

The variety of trees in an urban area is crucial to the ecosystem services they provide. The availability of suitable seedlings in urban nurseries, inadequate species selection, and a lack of expert knowledge have all contributed to the current decline in tree diversity in urban areas. From three lakefront vegetation groups, 2322 individuals belonging to 118 tree species in 39 families were recorded. The origin investigation of tree species revealed that 39% were foreign and 61% were native. *Swietenia mahagoni*, *Mangifera indica*, *Cocos nucifera*, *Khaya anthotheca* and *Delonix regia* are the top five most abundant tree species. Three of the five most common tree species are foreign species. *Swietenia mahagoni*, *Samanea saman*, *Cocos nucifera*, *Mangifera indica* and *Delonix regia* are the most dominant tree species, according to the significance value index. Similarly, three of the top five dominating tree species are non-native species. The research regions had the highest concentration of decorative tree species, followed by medicinal, fruit-bearing, timber-producing, and wildlife-supporting species. A comparison of the species richness of the three lakeside vegetation areas revealed that Dhanmondi Lakeside had the highest species richness (93), followed by Hatirjheel (83) and Gulshan (77). The highest Shannon diversity index value is observed in Dhanmondi (3.78), with Gulshan (3.41) and Hatirjheel (3.34) following

closely behind. Based on the opinions of visitors, 85% of respondents supported positive action for the three lakesides' vegetation management issues, such as enhancing native plantations, addressing exotic dominance, raising the proportion of native to exotic species, growing multipurpose tree species, and planting heritage plant species. They also preferred expert consultation for the general administration of the research area. The research area's tree diversity was found to be threatened by several factors, such as the dominance of exotic species, spontaneous tree falls, a scarcity of native seedlings, a lack of experience and understanding in plantations, and a low level of public awareness. Several suggestions were made for managing the diversity of trees in three lakeside vegetation areas based on the study's current findings. These included making more native species the dominant species, gradually displacing exotics, increasing the number of trees that support wildlife and other uses, increasing public awareness, and eventually implementing the advice of experts (taxonomists, ecologists, foresters, and conservationists) in urban plantation programs.

Recommendations

Based on observations and discussions with visitors, a number of threats to tree diversity were determined. Trees falling during a rainy season are one of the threats. The shallow and bushy roots cannot provide support to withstand the soil during rain and gusty wind. The wrong selection of tree species for plantations is another threat to reducing tree diversity in the lakeside vegetation. Contractor-based plantation programs create favor to lead exotics in lakeside vegetation. In some cases, financial constraints are a big problem for taking steps to green native tree species. Lack of awareness and taxonomic education in planners creates confusion in choosing native tree species for the greenery.Taxonomists advice was not sought during the species selection process for plantations.

Based on the present study, observations, and visitors' perceptions, a number of recommendations were made for proper management of the lakeside tree vegetation of Dhanmondi, Hatirjheel, and Gulshan Lake. A long-term master plan should be developed involving all concerned stakeholders in Dhaka city; the current dominant tree diversity of exotic species should be under management; if necessary, those can be replaced by native tree diversity; Native multipurpose tree species should be given priority in the plantation list; the knowledge of concerned experts should be sought during the finalization of the tree plantation list. Rare, threatened, and of conservation significance tree species should be given priority in the plantation list; for the promotion of ecosystem services, all utility categories of native tree species should be kept in mind during the planning process to enrich the lakeside vegetation; Wildlife promoting and biodiversity augmenting native and local tree species should be considered in plantations;Original and native floristic components of Dhaka division should be resotored as possible as can; local nurseries should be established to expand the range of native uncommon species, species that support wildlife, and species of therapeutic plants; awareness programs should be undertaken among the stakeholders; and at least one plant taxonomist should be required in the concerned departments for those involved in the development of lakeside vegetation.

Acknowledgement

The authors acknowledged the financial contribution of the Ministry of Science and Technology, Government of the People's Republic of Bangladesh. They also remember the supports obtained during data collection from fellow research friends.

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(Manuscript received on 30 May 2023; revised on 30 November 2023)