Eco. Env. & Cons. 27 (3) : 2021; pp. (1357-1366)
Copyright@ EM International
ISSN 0971–765X

Phytosociological analysis and species diversity around Najafgarh Lake, Delhi NCR, India

Priyanka Verma, Aakanksha Kasania and Pamposh*

University School of Environment Management, Guru Gobind Singh Indraprastha University, Sector-16C Dwarka, New Delhi 110 078, India

(Received 24 April, 2021; Accepted 7 June, 2021)

ABSTRACT

Najafgarh Lake is located in the southwest part of Delhi straddling Haryana and Delhi border. Every year hundreds of migratory birds visit the lake and most of the studies have been concentrating on bird diversity. The present study was undertaken around Najafagrh lake from 2018-2019 to evaluate the plant community structure of the area. The data was quantitatively analyzed for different community characteristics. A total number of 33 species, representing 32 genera from 21 families of aquatic and terrestrial plant species were recorded in the study site. The most common plant species based on the importance value index in tree species were *Eucalyptus* sp. (IVI=54.32) followed by *Azadirachta indica* A.Juss. (IVI=52.21) and *Prosopis juliflora* (Sw.) DC (IVI=42.19). Among the herb and shrub species, the dominating species were *Alternanthera philoxeroides* (Mart.) Griseb. (IVI= 47.38), *Cynodon dactylon* (L.) Pers. (IVI=46.3) followed by *Saccharum* sp. (IVI=39.31) and *Ricinus communis* L. (IVI=37.65) respectively. The dominant diversity curve showed log-normal series for trees, herbs, and shrubs. The maximum species diversity was observed at Dhansa barrage and upstream canal region. This study provides baseline information on the vegetation around the Najafgarh Lake area. Appropriate conservation and management can considerably improve the botanical value of vegetation around the lake area, and consequently their value for other life forms.

***Key words**: Phytosociology, Species diversity, Terrestrial plants, Najafgarh lake, Importance value index, Community structure*

Introduction

Vegetation is an important component of the ecosystem that affects the entire environment Billings (1952); Shahid and Joshi (2016). Herbaceous vegetation structure changes from one season to another in a cyclic manner. These changes are mostly governed by moisture, heat, and rainfall Heady (1958); Shameem *et al.* (2010); Shahid and Joshi (2016). In a vegetational study, phytosociological analysis plays a key role Singh *et al*. (2017). Interaction of different plant species among themselves and their environment leads to the formation of discrete vegetation structures Mishra *et al*. (1997).

Ecosystem health is closely linked to plant biodiversity, particularly in urban areas because they are already affected by anthropogenic pressure Schafer (2011), therefore vegetation is the first step towards ecosystem conservation. Such research may be useful for determining the degree of adaptation to the environment and its ecological significance. Pascal and Pelissier (1996).

Phytosociology is a qualitative study of the vegetation structure of a particular area, highlighting the quantitative relationship between a few dominant species that control the community and also identifying a large number of rare species Sharma and Pandey (2010). A phytosociological analysis is

(*Assistant Professor)

a prerequisite for understanding the ecology and functioning of any community Shahid and Joshi (2016). As per phytosociological studies, the organization and structure of plant diversity define the distribution pattern of individuals among species in a given habitat Rout *et al.* (2018). Oosting (1959) suggested the importance of phytosociological parameters for spatial problems in the sociological behavior of plants. In India, phytosociological work started far back before independence in 1920 Bharucha (1975). Various studies dealt with analyzing the phytosociological structure of the forests Sharma and Upadhyaya (2002); Kukshal *et al.* (2009); Shahid and Joshi (2015); Bagul and Patil (2019), and others dealt with herbaceous and shrub vegetation of wetland areas Mir *et al.* (2009) Mukherjee and Sarma (2014); Singh *et al.* (2015). Several other studies dealt with different ecosystem types Mishra *et al.*(1997); Sharma and Pandey (2010); Rout *et al.* (2018).

The study was carried out in the area around Najafgarh Lake which is located in the southwest district of Delhi and Gurugram district of Haryana. Najafgarh Lake is the water body originally spread over 220 sq. km which is reduced to only 5 sq. km DLF (2018). This natural depression obtains water from west of the ridge, north Karnal, and Sahibi Nadi from Rajasthan and the catchment area lying in Gurugram. This area is characterized by a high diversity of vegetation and is also surrounded by agricultural fields and villages.

The present investigation aims to analyze the phytosociological characteristics and the diversity pattern of the herbaceous plants of the area around Najafgarh Lake. The data generated from this study would help understand the importance of Najafgarh Lake and maintaining the ecological balance of the region.

Study site

Najafgarh Lake is located in the southwest part of NCT Delhi covering Najafgarh Block and the northwestern part of Gurugram district, Haryana. It is a 7 km stretch that is straddling the Delhi Haryana border equally from which 5 sq. Km. of the area remains underwater perennially. Najafgarh lake (28º33′37.51″N and 76º54′32.64″N) is predominantly surrounded by agricultural landscapes and villages. Currently, the portion of the jheel located in Delhi is privately owned across five villages Rawta, Ghumanhera, Jainpur, Shikarpur, and Jhatikra Shrangi (2019). It works as an important source of groundwater and a surface water supply to nearby agricultural fields and villages. This natural depression gets filled up during monsoon season in years with adequate rainfall. Every year flocks of flamingos, common cranes, sarus crane, painted storks, black-necked storks, and other migratory birds visit the lake.

The study included the periphery of the lake and canal region. The site was majorly divided into four parts, Dhansa barrage region (3 points), upstream canal region (3 points), lake region (3 points), and the downstream canal (1point) (Fig. 1). The study site is stretched at a length of 17.18 km covering all the points (Fig. 2).

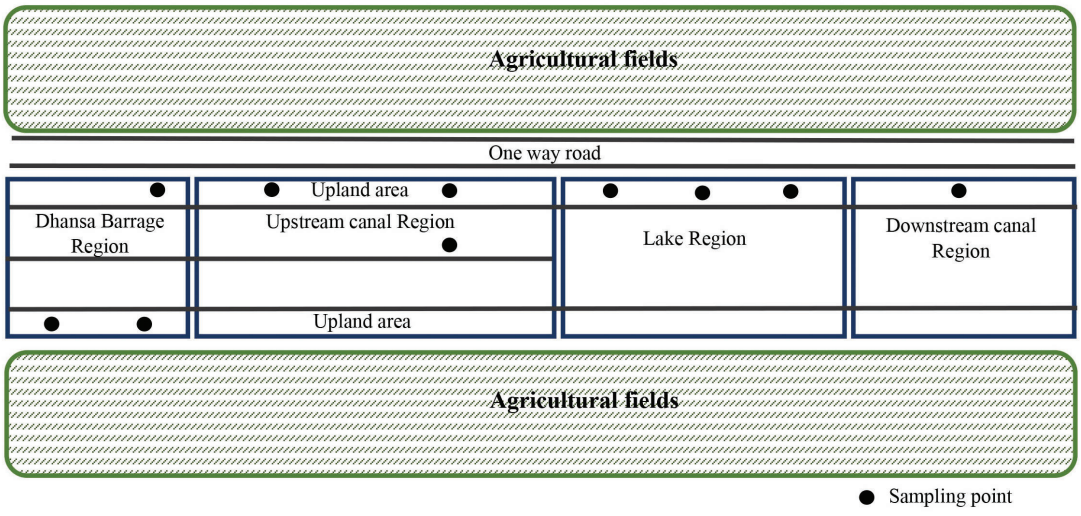

Fig. 1. Flow diagram of study site showing sampling points

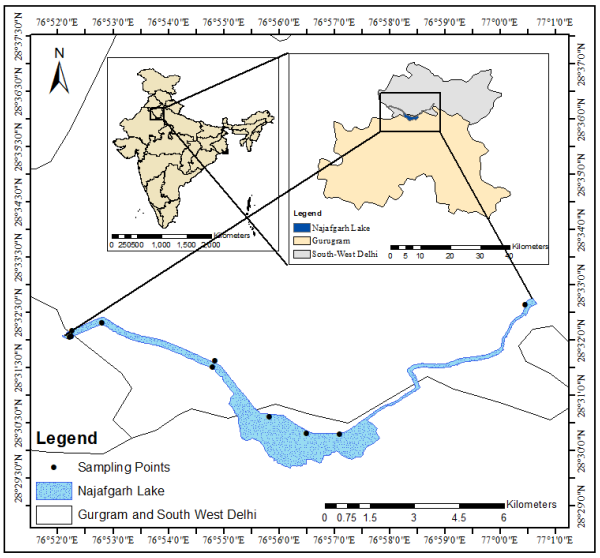

Fig. 2. Map of Najafgarh lake showing sampling points

Methodology

Vegetation Sampling

In present study the vegetation sampling was carried out from 2018 to 2019. The selection of the site for phytosociological analysis was done after assessing the total area. At each point, ten, 1m x 1m (1 m^2), 5m x 5m (25m^2) and 20m x 20m (400 m^2) quadrats were laid down randomly for herbs, shrubs and trees respectively. Later the number of points were increased which will decide the total number of quadrats in the whole site (e.g., 10 points _ 10 quadrats_ 100 quadrats total). The number of individuals of each herb species was counted to estimate the diversity, frequency, density, abundance, IVI, and basal area cover. Using prescribed method, the data was quantitively analyzed for population characteristics such as species richness, dominance, diversity and distribution pattern Whitford, (1948); Simpson (1949) Curtis and Mclntosh (1950); Margalef (1958); Philips (1959); Shannon and Weiner (1968); Mishra (1968).

$$\text{Frequency} = \frac{\text{toal no. of quadrats in which the species occured}}{\text{Total no. of quadrats studied}} \times 100$$

$$\text{Relative frequency \%} = \frac{\text{Frequency of the species}}{\text{Frequency of all the species}} \times 100$$

$$\text{Density} = \frac{\text{Total no. of individual of the species}}{\text{Total no. of quadrats studied}}$$

$$\text{Relative density\%} = \frac{\text{No. of individual of the species}}{\text{No. of individual of all the species}} \times 100$$

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

$$\text{Relative dominance \%} = \frac{\text{Basal area of the species}}{\text{Basal area of all the species}} \times 100$$

Importance Value index = Relative frequency+ Relative density + Relative dominance

Shannon Wiener Index $(H') = -\sum_{i=1}^{s} p_i \ln p_i$

Where, s = the number of species, pi = the proportion of individuals or abundance of the ith species expressed as a proportion of total cover, ln = log base n

Alpha diversity (α) is within area diversity, measured as the number of species occurring within an area of a given size Huston (1994). It is therefore a measure of the richness of a potentially interactive assemblage of species.

$$\textit{Simpson dominance index}(D) = \sum_{i=1}^{s} p_i^{\,2}$$

Where, pi= $\frac{n}{N}$, n = the total number of organisms of a particular species, N = the total number of organisms of all species

$$\textit{Simpson index of diversity} = 1\text{-}D$$

Where, D = Simpson dominance index

$$\textit{Species eveness} = J = \frac{H'}{H'_{max}} = \sum_{i=1}^{s} \frac{p_i \ln p_i}{\ln S}$$

where, s = the number of species, pi = the proportion of individuals or abundance of the ith species expressed as a proportion of total cover, ln = log base n.

Whitford Index $(A/F \text{ ratio}) = \frac{A}{F}$

Where, A= Abundance and F= Frequency Whitford (1948)

if A/F ratio <0.025: Regular distribution

0.025-0.05: Random distribution

>0.05: Contagious or clumped distribution

The plant species specimen were collected and identified on the field. These specimens were later transported to the laboratory for pressing and drying in the plant presses. The unidentified species in the field were identified with the help of 'The Flora

of Delhi' Maheshwari (1963) and 'Trees of Delhi: A field guide 'Nayar (2006).

Results and Discussion

A total of 33 species, representing 32 genera from 21 families, were recorded from the studied quadrates. *Amaranthaceae (3)*, *Asteraceae (3)*, *Fabaceae (3),* and *Solanaceae (3)* were the dominant families followed by *Convolvulaceae* (2), *Euphorbiaceae* (2), *Poacaea* (2), and *Ranunculaceae* (2) while the other 12 families represent only one species (Table 1). Out of 33 species, 24 species are terrestrial species and 9 are aquatic species which include submerged, free-floating, and emergent vegetation. The vegetation studied includes 18 herbaceous species, 8 shrub species, 5 tree species, and 2 vines (Table 1). The herbaceous plants mainly included 15 perennial, 11 annuals, and 7 species which are both perennial or annual (Table 1). Floristic composition of 10 sampling points shows that *Cynodon dactylon (L.) Pers.* (constancy=100%) was observed at all the 10 sampling points followed by *Saccharum sp*. (constancy = 80%) (Table 4).

Dominance pattern

Natural vegetation in a certain area represents the interaction among plants, animals, soil types, and various climatic factors. Based on the IVI values determined, the dominance of species was assigned. Distribution analysis of the plant species adjacent to Najafgarh lake and the area around showed that the dominating species among the tree species were *Eucalyptus sp*. (IVI=54.32, SDI= 0.000005) followed by *Azadirachta indica A. Juss.* (IVI=52.21, SDI= 0.000004) and *Prosopis juliflora* (Sw.) *DC* (IVI=42.19, SDI= 0.000671). Among the herb and shrub species, the dominating species were *Alternanthera philoxeroides* (Mart.) Griseb. (IVI=47.38, SDI= 0.024272), *Cynodon dactylon* (L.) Pers. (IVI=46.3, SDI= 0.194229) followed by *Saccharum* sp. (IVI=39.31, SDI= 0.025975) and *Ricinus communis* L. (IVI= 37.65, SDI = 0.000078). *Cynodon dactylon* (L.) *Pers.* was found to be dominated by almost all the points of sampling. The frequency and abundance of *Cynodon dactylon* (L.) *Pers.* were found to be maximum as it is a cosmopolitan species that can survive in every type of environmental condition (Table 2).

The dominance diversity curves showed a log-normal series of distribution for trees, shrubs and herbs during the study period (Fig. 3). The best distribution of species-abundant pattern is the log-normal distribution Preston (1948); Kaur *et al*. (2020), as this pattern is expected to have large or heterogenous assemblages of species in which resources are

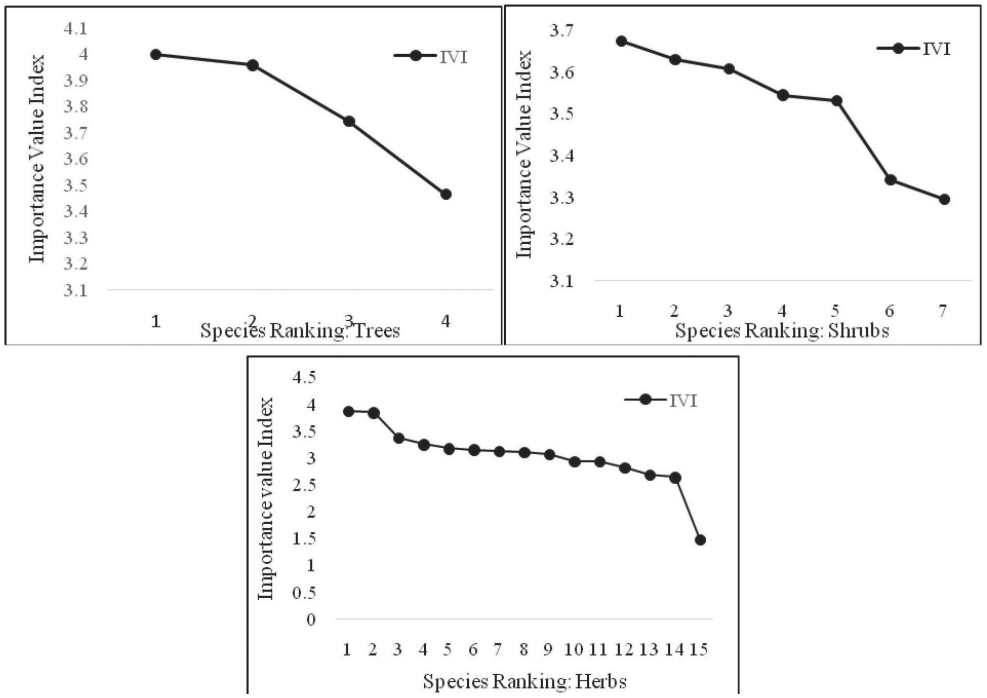

Fig. 3. Dominant diversity (DD) curves of plant species

Table 1. Plant species found in Najafgarh Lake

Plant Species	Common name	Habit	Life cycle	Habitat
Amaranthaceae				
Achyranthes aspera L.	Devil's horsewhip	Herb	Per.	Ter.
*Alternanthera philoxeroides (*Mart.*)* Griseb.	Alligator weed	Herb	Per.	Ter.
Chenopodium album L.	Lamb's quarters, Goose foot	Herb	Ann.	Ter.
Asclepiadaceae				
Calotropis procera (Ait.) R. Br.	Apple of Sodom, King's crown	Shrub	Per.	Ter.
Asteraceae				
Parthenium hysterophorus L.	Congress grass	Herb	Ann.	Ter.
Tagetes erecta L.	Mexican Marigold	Herb	Ann.	Ter.
Vernonia cinerea (L.) Less.	Dandotapala, Sadodi	Herb	Ann.	Ter.
Cannabaceae				
Cannabis sativa L.	Marijuana, Hemp	Herb	Ann.	Ter.
Convolvulaceae				
Convolvulus arvensis L.	Field bindweed	Vine	Per.	Ter.
Ipomea aquatica Frossk.	Water spinach	Vine	Ann./Per.	Aq.
Euphorbiaceae				
Croton bonplandianum Balli.	Rushfoil, Croton	Herb	Ann.	Ter.
Ricinus communis L.	Castor plant	Shrub	Ann./Per.	Ter.
Fabaceae				
Acacia nilotica subsp. indica	Babool, kekkar, Egyptian thorn	Tree	Per.	Ter.
Dalbergia sisso Sensu Miq.	Indian rose wood	Tree	Per.	Ter.
Prosopis juliflora (Sw.) DC.	Mesquite, Vilayti Kekkar	Tree		Ter.
Hydrocharitaceae				
Hydrilla verticillata (L.f.) Royle	Water thyme	Herb	Per.	Aq.
Malvaceae				
Abitulon indicum L.	Indian mallow	Shrub	Per.	Ter.
Meliaceae				
Azadirachta indica A.Juss.	Neem	Tree	Per.	Ter.
Myrtaceae				
Eucalyptus sp.	Forest red gum	Tree	Per.	Ter.
Papaveraceae				
Argemone mexicana L.	Mexican prickly poppy	Shrub	Ann./Per.	Ter.
Phyllanthaceae				
Phyllanthus reticulatus Poir.	Black honey shrub	Shrub	Per.	Ter.
Poaceae				
Cynodon dactylon(L.) Pers.	Bermuda grass	Herb	Per.	Ter.
Saccharum sp.	Sugarcane	Shrub	Per.	Aq.
Polygonaceae				
Rumex crispus L.	Curly dock	Herb	Ann./Per.	Aq.
Pontederiaceae				
Eichhornia crassipes (Mart.) Solms	Water hyacinth	Herb.	Per.	Aq.
Ranunculaceae				
Ranunculus muricatus L.	Spiny fruit buttercup	Herb	Ann.	Aq.
Ranunculus sceleratus L.	Cursed buttercup	Herb	Ann./Per.	Aq.
Salviniaceae				
Azolla pinnata R. Br.	Swamp morning Glory	Herb	Ann./Per.	Aq.
Scrophulariaceae				
Verbascum chinense (L.) Santapau	Chinese Mullein	Herb	Ann.	Ter.
Solanaceae				
Datura inoxia Mill.	Downy thorn apple	Shrub	Ann.	Ter.
Nicotiana plumbaginifolia Viv.	Tex-mEx Tobacco	Herb	Ann.	Ter.
Solanum nigrum L.	European black nightshade	Herb	Ann.	Ter.
Verbenaceae				
Lantana camara L.	Big sage	Shrub	Per.	Ter.

Note: Ann= Annual, Per= Perennial, Ter= Terrestrial, Aq= Aquatic

Table 2. Frequency, density, abundance, A/F ratio, and IVI of plant species around Najafgarh Lake

Plant species	F (%)	D	A	A/F Ratio	SDI	IVI
Abitulon indicum L.	4	0.15	3.8	0.94	0.000008	26.95
Achyranthes aspera L.	9	0.66	7.3	0.81	0.000160	25.59
*Alternanthera philoxeroides (*Mart.*)* Griseb.	24	8.12	33.8	1.41	0.024272	47.38
Argemone mexicana L.	2	0.07	3.5	1.75	0.000002	34.56
Azadirachta indica A.Juss.	6	0.1	1.7	0.28	0.000004	52.21
Calotropis procera (Ait.) R. Br.	5	0.12	2.4	0.48	0.000005	34.11
Cannabis sativa L.	10	0.56	5.6	0.56	0.000115	28.84
Chenopodium album L.	8	1.77	22.1	2.77	0.001153	23.61
Convolvulus arvensis L.	8	0.18	2.3	0.28	0.000012	21.34
Croton bonplandianum Balli.	17	2.34	13.8	0.81	0.002016	22.47
Cynodon dactylon (L.) Pers.	31	22.97	74.1	2.39	0.194229	46.34
Dalbergia Sisso Sensu Miq.	7	0.23	3.3	0.47	0.000019	31.95
Datura inoxia Mill.	5	0.24	4.8	0.96	0.000021	28.21
Eucalyptus sp.	6	0.12	2.0	0.33	0.000005	54.32
Lantana camara L.	10	0.16	1.6	0.16	0.000009	36.78
Nicotiana plumbaginifolia Viv.	5	0.68	13.6	2.72	0.000170	22.23
Parthenium hysterophorus L.	10	0.72	7.2	0.72	0.000191	18.53
Prosopis juliflora (Sw.) DC.	31	1.35	4.4	0.14	0.000671	42.19
Ranunculus muricatus L.	7	0.56	8.0	1.14	0.000115	16.63
Ranunculus sceleratus L.	2	0.02	1.0	0.50	0.00000015	14.53
Ricinus communis L.	13	0.46	3.5	0.27	0.000078	37.65
Rumex crispus L.	16	1.46	9.1	0.57	0.000785	23.11
Saccharum sp.	35	8.4	24.0	0.69	0.025975	39.31
Solanum nigrum L.	11	0.45	4.1	0.37	0.000075	18.63
Tagetes erecta L.	3	0.05	1.7	0.56	0.000001	4.36
Vernonia cinerea (L.) Less.	4	0.18	4.5	1.13	0.000012	13.84

Note: F= Frequency (%), D=Density, A=Abundance, SDI= Simpson diversity index, IVI= Importance value index

more or less evenly distributed among the members of the important species.

Distribution Pattern

The ratio of abundance to frequency is used to determine the distribution of the species in a population. Plant distribution is entirely dependent on the physico-chemical composition of the ecosystem as well as the reproductive biology of the species themselves. It was discovered that in the study area, regular and random plant distribution was completely absent and almost every species was spread contagiously. Trees, shrubs, and herbs showed a 100% contagious type of distribution (Table 3 and Fig. 4). The study area being a part of a disturbed ecosystem having harsh environmental conditions, the findings are in accordance with Odum (1971) who revealed contagious distribution is common in nature and formed as a result of small and significant changes in the ambient environmental conditions. It also reveals that the resources are allocated in pockets due to anthropogenic disturbances.

Table 3. Distribution pattern of Vegetation

Distribution type	% Vegetation
Trees	
Regular	0
Random	0
Contagious	100
Shrubs	
Regular	0
Random	0
Contagious	100
Herbs	
Regular	0
Random	0
Contagious	100

Diversity Measurements

Alpha diversity (α) is within area diversity, measured as the number of species occurring within an area of a given size Huston (1994). It is therefore a measure of the richness of a potentially interactive

assemblage of species. It was found to be maximum at Point 8 (15) and Point 10 (15) followed by Point 6 (12) and Point 5 (11). Point 8 and 10 correspond to the Dhansa barrage and upstream canal region respectively and are more diverse because the water is cleaner and is separated from agricultural areas, while Points 3 and 1 correspond to the lake and downstream canal region, respectively which is adjacent to urbanized areas and agricultural land making it more prone to anthropogenic activities such as dredging activities in the lake, input from Badshapur drain and return flow from the agricultural fields. The highest H′ (2.114) was recorded at Point 6 followed by Point 9 (1.884) and the lowest was observed at Point 3 (1.331). Evenness is a measure of the relative abundance of the various species making up the richness of an area Supriatna (2018). The maximum value of evenness (J) (0.375) was recorded at Point 6 followed by Point 9 (0.371) and the lowest was recorded at Point 1 (0.157). A community dominated by one or two species is considered to be less diverse than one in which there is an equal abundance of many distinct species. The simpson's diversity index is a diversity metric that takes the number of species present and the relative abundance of each species into account Simpson (1949); Supriatna (2018). As the richness and evenness of species increase, diversity increases. The maximum simpson's index of diversity was observed at Point 6 (0.84) followed by Point 9 (0.80) and the lowest was recorded at Point 2 (0.53) (Table 5).

Conclusion

Najafgarh Lake is the largest water body found in Delhi after the Yamuna River. It plays a crucial role in maintaining and sustaining the environment. It harbors migratory birds for years despite experiencing a high rate of anthropogenic activities and exploitation. As a prerequisite, scientific documentation of the terrestrial and aquatic plants found around the lake is mandatory for management and conservation practices. The present study surely provides some benchmark of the flora and nutritional status for future development and management practices. A total of 33 species were found, out of which 24 species were terrestrial species and 9 were aquatic species which included submerged, free-floating, and emergent vegetation. Maximum diversity was observed at the Dhansa barrage region and upstream canal region, as these parts are comparatively cleaner and less disturbed as com-

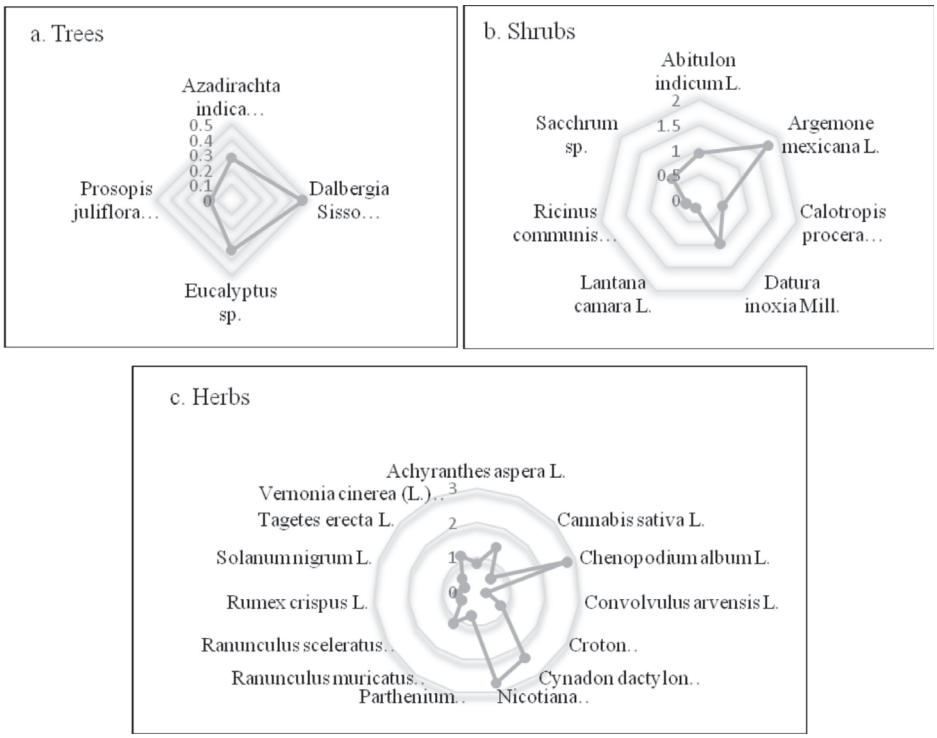

Fig. 4. Distribution pattern of Vegetation a. Tree b. Shrubs and c. Herbs

Table 4. Floristic composition of ten sampling points.

Plant species	P 1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Constancy %
Abitulon indicum L.	-	-	-	-	+	-	+	-	-	+	30%
Acacia nilotica	-	-	-	-	-	+	-	-	-	-	10%
Achyranthes aspera L.	-	-	-	-	-	-	-	+	+	+	30%
Alternanthera philoxeroides (Mart.) Griseb.	+	+	+	+	+	-	-	-	-	-	50%
Argemone mexicana L.	-	-	-	-	+	-	-	+	-	-	20%
Azadirachta indica A.Juss.	-	-	-	-	-	-	-	+	+	+	30%
Calotropis procera (Ait.) R. Br.	-	-	-	-	-	+	+	-	+	+	40%
Cannabis sativa L.	-	-	-	-	-	+	+	-	-	-	20%
Chenopodium album L	-	-	-	-	-	+	+	-	-	+	30%
Convolvulus arvensis L.	-	-	-	-	-	+	+	+	-	+	40%
Croton bonplandianum Balli.	-	-	-	-	+	+	+	+	+	+	60%
Cynodon dactylon (L.) Pers.	+	+	+	+	+	+	+	+	+	+	100%
Dalbergia sisso Sensu Miq.	-	-	+	+	-	+	-	-	-	-	30%
Datura inoxia Mill.	-	+	-	-	+	+	-	-	-	-	30%
Eucalyptus sp.	-	-	-	-	-	-	-	+	+	+	30%
Lantana camara L.	-	-	+	-	-	-	+	+	+	+	40%
Nicotiana plumbaginifolia Viv.	-	-	-	-	-	-	-	+		+	20%
Parthenium hysterophorus L.	-	-	+	+	+	+	-	+	-	-	50%
Phyllanthus reticulatus Poir.	-	-	-	+	-	-	-	-	-	-	10%
Prosopis juliflora (Sw.) DC.	+	+	+	+	+	+	+	+	+	+	100%
Ranunculus muricatus L.	-	+	-	+	+	-	-	-	-	-	30%
Ranunculus sceleratus L.	+	-	-	-	-	-	-	-	-	-	10%
Ricinus communis L.	-	-	-	-	-	+	+	+	-	+	40%
Rumex crispus L.	+	-	+	+	+	-	-	-	-	-	40%
Saccharum sp.	+	+	+	+	+	-	-	+	+	+	80%
Solanum nigrum L.	-	+	-	-	-	-	-	+	+	+	40%
Tagetes erecta L.	+	+	-	-	-	-	-	-	-	-	20%
Vernonia cinerea (L.) Less.	-	-	-	-	-	-	-	+	+	-	20%

Note: Presence (+), Absence (-), Pn = sampling point

Table 5. Diversity of species at different sampling points

Diversity Indices	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Alpha diversity (α)	7	8	8	9	11	12	10	15	11	15
Simpson dominance index	0.43	0.47	0.36	0.23	0.30	0.16	0.23	0.31	0.20	0.23
Simpson index of diversity	0.57	0.53	0.64	0.77	0.7	0.84	0.77	0.69	0.8	0.77
Shannon weiner index	1.084	1.056	1.331	1.704	1.477	2.114	1.663	1.666	1.884	1.857
Species evenness	0.157	0.162	0.212	0.255	0.227	0.375	0.276	0.275	0.371	0.330

Note: Pn = sampling point

pared to the lake and downstream region of the canal. The lake area is fed by the Badhshapur drain which leads to contamination owing to less diversity. The downstream part of the lake is much more contaminated as it is surrounded by urbanized areas along with other drains joining in. Major invasive species observed during the study were *Prosopis juliflora, Parthenium hysterophorous, Lantana Camara, Eichhornia crassipes, Alternanthera philoxeroides.* Amongst major factors that influenced vegetation structure are human disturbance, extensive grazing, trampling, invasion of opportunistic species, and soil erosion. Species diversity is majorly affected by changes in both macro and micro-environment. The natural communities are increasingly threatened by urban and industrial expansion and vegetation clearing. To manage and conserve Najafgarh lake and surrounding area, plantation of local vegetation should be promoted. The present study for the Najafgarh lake area is preliminary,

subsequent and re-census will be helpful for management and restoration of the vegetation and biodiversity on a larger scale.

Acknowledgment

The authors are grateful to Guru Gobind Singh Indraprastha University for Short Term Research Fellowship and Faculty Research Grant Scheme for carrying out the entire study. We would also like to thank the Dean, University School of Environment Management, for technical and research support. The authors wish to convey their sincere gratitude to the people concerned for their help in fieldwork.

References

Bagul, R.M. and Patil, M.A. 2019. Phytosociological Studies on the Vegetation of Manudevi, Vaijapur and Pal forest areas in Jalgaon district–Maturity Index. *International Journal of Research and Analytical Reviews*. 6(1): 231-233.

Bharucha, F.R. 1975. Fifty years of ecological and phytosociological research in India. *Vegetation*. 30 (3): 153-155.

Billings, W.D. 1952. The environmental complex in relation to plant growth and distribution. *The Quarterly Review of Biology*. 27: 251-265.

Clesceri, L.S., Greenberg, A.E. and Eaton, A.D. (Eds.) 2005. *Standards Methods for the Examination of Water and Wastewater* (twentieth edition). American Public Health Association, Washington DC.

Curtis, J.T. and McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*. 31 : 434-455.

Delhi land and finance foundation (DLF). 2018. Transformation of Najafgarh Basin in Gurgaon Rejuvenation project. Government of Haryana, India.

Heady, H.F. 1958.Vegetational changes in the California annual type. *Ecology*. 39 (3) : 402-416.

Huston, M.A. 1994. *Biological Diversity: The Coexistence of Species on Changing Landscapes*. Cambridge University Press. Cambridge. 681.

Kaur, M., Joshi, P., Sarma, K. and Das, S.K. 2020. Assessment of plant community structure in Tal Chhapar Wildlife Sanctuary, Rajasthan, India. *Species*. 21(67): 126-139.

Kukshal, S., Nautiyal, B.P., Anthwal, A., Sharma, A. and Bhatt, A.B. 2009. Phytosociological investigation and life form pattern of grazing lands under pine canopy in temperate zone, Northwest Himalaya, India. *Journal of Botanical Research*. 4 : 55-69.

Maheshwari, J. K. 1963. The flora of Delhi. Council of Scientific & Industrial Research.

Margalef, R. 1958. Information theory in ecology. *General System Yearbook.* 3 : 36-71.

Mir, A.A., Mahajan, D.M. and Saptarshi, P.G. 2009. Composition and distribution of macrophytes in Hokersar - A wetland of international importance in Kashmir Himalaya. *The International Journal of Climate Change: Impacts and Responses*. 1(4): 23-35.

Mishra, D., Mishra, T.K. and Banerjee, S.K. 1997. Comparative phytosociological and soil Physico-chemical aspects between managed and unmanaged lateritic land. *Annals of Forestry*. 5(1): 16-25.

Mishra, R. 1968. Ecology Workbook. Oxford & IBH Publishing Company, Calcutta. 242

Mukherjee, A. and Sarma, K. 2014. Community structure of plant species in Okhla Bird Sanctuary, Delhi, India. *International Journal of Conservation Science*. 5(3).

Nayar, E.R. 2006. Trees of Delhi–A Field Guide by Pradip Krishan. *Indian Journal of Plant Genetic Resources*. 19 (1): 139-140.

Odum, E.P. 1971. *Fundamentals of Ecology*. Saunders, Philadelphia, USA, 574

Oosting, H.J. 1959. The study of plant Communities. W. H. Freeman & Co., San Francisco., Phillips, E.A. *Methods of Vegetation Study*., Henry Holt & Co Inc.

Pascal, J.P. and Pelissier, R. 1996. Structure and floristic composition of tropical evergreen forest in southwest India. *Journal of tropical Ecology*. 12(2) : 191–214

Philips, E.A. 1959. *Methods of Vegetation Study.* Henri Holt Co Inc, New York. 107.

Preston, F.W. 1948. The commonness and rarity of species. *Ecology*. 29 : 254-283.

Rao, P. S., Sujatha, B., Lakshminarayana, K. and Ratnam, S. V. 2013. A study on phytosociology, soil conservation and socio-economic aspects in red sand dunes near Bhimili of Visakhapatnam. *Archives of Applied Science Research.* 5(1) : 45-56.

Rout, S.D., Panda, S.K. and Panda, T. 2018. Phytosociological and floristic evaluation of Kuldiha Wildlife Sanctuary, Odisha, India. *Tropical Plant Research*. 5 (3): 419-430.

Schafer, R.B. 2011. Biodiversity, ecosystem functions and services in environmental risk assessment: Introduction to the special issue. *Science of the Total Environment*. 15 : 1–2

Shahid, M. and Joshi, S.P. 2015. Life-forms and Biological Spectrum of Dry Deciduous Forests in Doon Valley, Uttarakhand, India. *International Journal of Environmental Biology*. 5(1) : 1–10

Shahid, M. and Joshi, S.P. 2016. Phytosociological assessment and distribution patterns of tree species in the forests of Doon Valley, Shivalik hills of lower Himalaya. *Tropical Plant Research*. 3(2) : 263-271.

Shameem, S. A., Soni, P. and Bhat, G.A. 2010. Comparative study of herb layer diversity in lower Dachigam National Park, Kashmir Himalaya, India. *International Journal of Biodiversity Conservation*. 2(10) : 308-315.

Shannon, C.E. and Weiner, W. 1963. *The Mathematical Theory of Communication*. Urbana: University of Illinois Press. 117.

Sharma, K.K. and Pandey, A.K. 2010. Phytosociological study of vegetation of some selected arid region of the Thar desert of Rajasthan, India. *Current World Environment*. 5(1) : 51.

Sharma, K.P. and Upadhyaya, B.P. 2002. Phytosociology, primary production and nutrient retention in herbaceous vegetation of the forestry arboretum on the Aravalli hills at Jaipur. *Tropical Ecology*. 43(2): 325-335.

Shrangi, V. 2019. Delhi Government mulls notifying Najafgarh lake as a wetland, survey soon, Hindustan Times: Retrieved from https://www.hindustantimes.com/delhi-news/delhi-government-mulls-notifying-najafgarh-lake-as-a-wetland-survey-soon/story-Fk01XtwLcXwWoOs5JGTyXO.html

Simpson, E.H. 1949. Measurement of diversity. *Nature*. 163: 688.

Singh, A.K., Singh, C.S. and Sahani, R.K. 2017. Floristic and phytosociological studies of GB Pant Lake wetland vegetation, Pipri, Sonbhadra, (UP). *Indian Journal of Scientific Research.* 77-80.

Supriatna, J. 2018. Biodiversity Indexes: Value and Evaluation Purposes, Proceedings of E3S Web of Conferences (Vol. 48, p. 01001). *EDP Sciences*.

Whitford, P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. *Ecology*. 30: 199-208.