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Research article

Habitat characterization and plant community classification of Surajpur Reserve Forest: a potential bird sanctuary in National Capital Region, India

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Abstract: Surajpur Reserve Forest is a prominent forested wetland site in the National Capital Region, India, known for its rich floral and faunal biodiversity. The present study was conducted to assess the habitat characteristics, vegetation composition and plant community classification from March 2010 to February 2013. Stratified random sampling techniques applied for sampling of vegetation in circular and quadrat plots and TWINSPAN analysis was used in PC-ORD Software for classification of plant communities. A total of 257 vascular plants belonging to 214 genera and 65 families were recorded, including a comprehensive herbarium of 267 plant specimens have been recorded from 3 major habitats (woodland, grassland and wetland) and 9 microhabitats. A maximum of 157 plants in woodland, 73 plants in grassland and 65 plants in wetland habitat were recorded. Flowering and fruiting plants recorded maximum in monsoon followed by summers and winters. Various life-forms include 144 herbs, 39 trees, 31 grasses, 20 climbers, 12 shrubs and 11 sedges. A total of 51% plant species as abundant and 14% plant species as rare have been recorded. Woodland habitat recorded maximum density and diversity of herbs and shrubs. Five dominant plant communities have been identified in terrestrial and 3 in wetland habitat. The results indicate that Surajpur wetland supports a mosaic of habitat which enables the conservation and protection of threatened flora and fauna in an urban environment. The conservation implications are discussed in light of the results hitherto unreported.

Keywords: Flora - Greater Noida - Habitat - Surajpur wetland - TWINSPAN - Vegetation structure.

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INTRODUCTION

Forests are renewable resources and have contributed substantially to the economic development of the country by providing goods and services to the mankind. Forests also have a major role in enhancing the quality of the environment and balancing the ecosystem. However, this forest wealth is dwindling due to overgrazing, overexploitation, encroachments, unsustainable practices, forest fire and indiscriminate sitting of development projects in the forest areas. Tropical forests constitute diverse ecosystems supporting rich biodiversity. These forests are disappearing at alarming rates owing to deforestation for extraction of timber and other forests products (Devi & Yadava 2006). Vegetation is an integral part of the landscape and is required for management planning (Singh & Rawat 1999). The classification and mapping of vegetation are fundamental tools for obtaining knowledge about habitat characteristics (Mueller-Dombois 1984) and its relationship with various flora and fauna existing in that forest habitat. Forest structure and composition have been used to assess the habitat characteristics (Gillespie & Walter 2001), which provides the suitable place for breeding and resting of various flora and fauna and in conserving the biodiversity. Forest structure, such as diversity, the density of plants and species composition, has been significantly correlated with faunal distribution patterns. These patterns of distribution have been shaped by historical and ecological factors that play different roles at both temporal and spatial scales (Vuilleumier & Simberloff 1980, Hutto *et al.* 1986, Cherril & McClean 1997, Gaston & Fuller 2009).

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Surajpur is one such example of Reserve Forest in outskirts of National Capital Region, representing the mosaic of habitats, which supports a diverse range of flora and fauna. It represents an excellent example of urban biodiversity conservation and reported 186 species of birds in different habitats (Ansari & Nawab 2015) hence recognized as a potential bird sanctuary in the National Capital Region, India. The inventorisation studies on flora of National Capital Region has done by several authors (Maheshwari 1963, Srivastava 2004, Vardhana 2007, Dash & Ahmedullah 2012, Chaudhary *et al*. 2012, Manral *et al*. 2013, Mishra *et al*. 2014, Ansari 2015, Ansari *et al.* 2016), but there is no systematic study has been made on habitat characterization in the National Capital Region or in Surajpur Reserve Forest, although it supports luxuriant growth of angiospermic flora and plays an important role in the plant species conservation. Therefore, the present study has been made to assess the habitat characterization, vegetation composition and plant community classification of Surajpur Reserve Forest, National Capital Region, India.

MATERIALS AND METHODS

Study area

Surajpur wetland (28°31.425′ N, 77°29.714′ E) is located in Dadri Tehsil of the district Gautam Budh Nagar, Uttar Pradesh and it comes under the purview of Delhi- National Capital Region (NCR) India (Fig. 1). The NCR comprises an urban conglomerate including Delhi, Faridabad, Gurugram, Ghaziabad and Gautam Budh Nagar (Noida and Greater Noida). The Greater Noida City is just 3 kilometers from Surajpur wetland is one of the best-planned cities and is the largest industrial townships of Asia (Joshi 2009). The study area falls in the Upper Gangetic Plain Biogeographic Zone (Rodgers *et al.* 2002) at an elevation of 184.7 m above mean sea level. The area is a reserve forest and spreads over 308 hectare including a water body of 108 hectares. The wetland is mainly rain-fed and other sources for water recharge are Hawaliya drain which is attached to Hindon River and Tilapta irrigation canal. The climate is tropical monsoon type and maximum rainfall occurs from July to October ranging from 400–500 mm and normally the rain depends on north-west monsoon. The minimum and maximum temperatures ranged between 6.86°C and 41.69°C, and highest temperature was observed during June and the lowest during January.

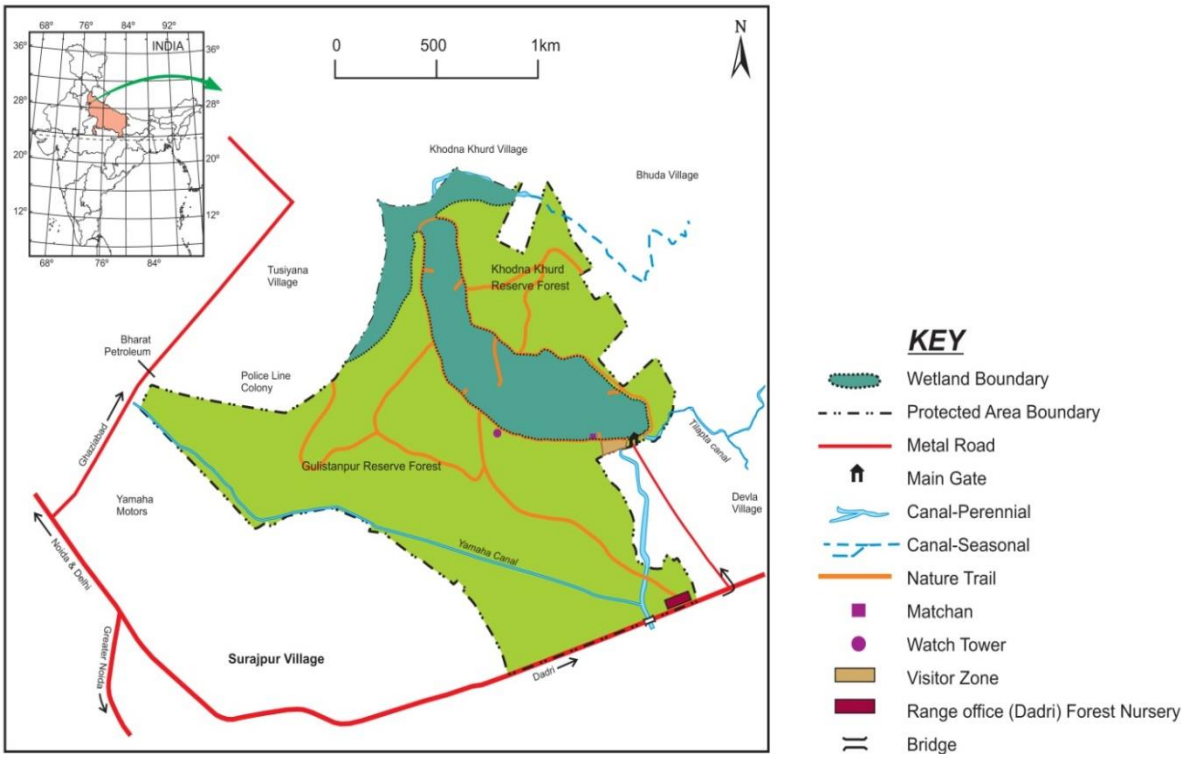

Figure 1. Map of the Surajpur Reserve Forest.

Habitat characterization

The present study was carried for the period of three years from March 2010 to February 2013 to explore the floral diversity of Surajpur forest. Intensive floristic surveys were made on monthly basis to collect the plant specimens and to prepare a comprehensive herbarium following Jain & Rao (1977) and Singh & Subramaniam (2008). The modern system of classification followed (APG III 2009, Haston *et al*. 2009, IPNI 2013, The Plant

List 2013). The frequency of occurrence of plant species was assigned into 4 abundance categories, A= Abundant (>50), F= Frequent (30–50), O= Occasional (10–30) and R= Rare (<10).

On the basis of dominant floristic composition and soil type, the study area was categorized into 3 major habitats: woodland, grassland and wetland. These major habitats further divided into several microhabitats (Fig. 2). The woodland habitat characterized by trees, grassland habitat by grasses and wetland habitat by various aquatic species. Wetland area has been further characterized by marshland and deep water area. The habitat condition varies according to different seasons. The floristic composition also changes accordingly, from summer to monsoon, from monsoon to winter and from winter to summer and monsoon respectively. The various habitats have been quantified based on surveys of flora, water quality, soil quality, air quality and availability of water from season to season in the wetland area. The measurements were done on monthly basis by standard techniques to calculate the changes in habitat conditions and subsequent maps have been prepared.

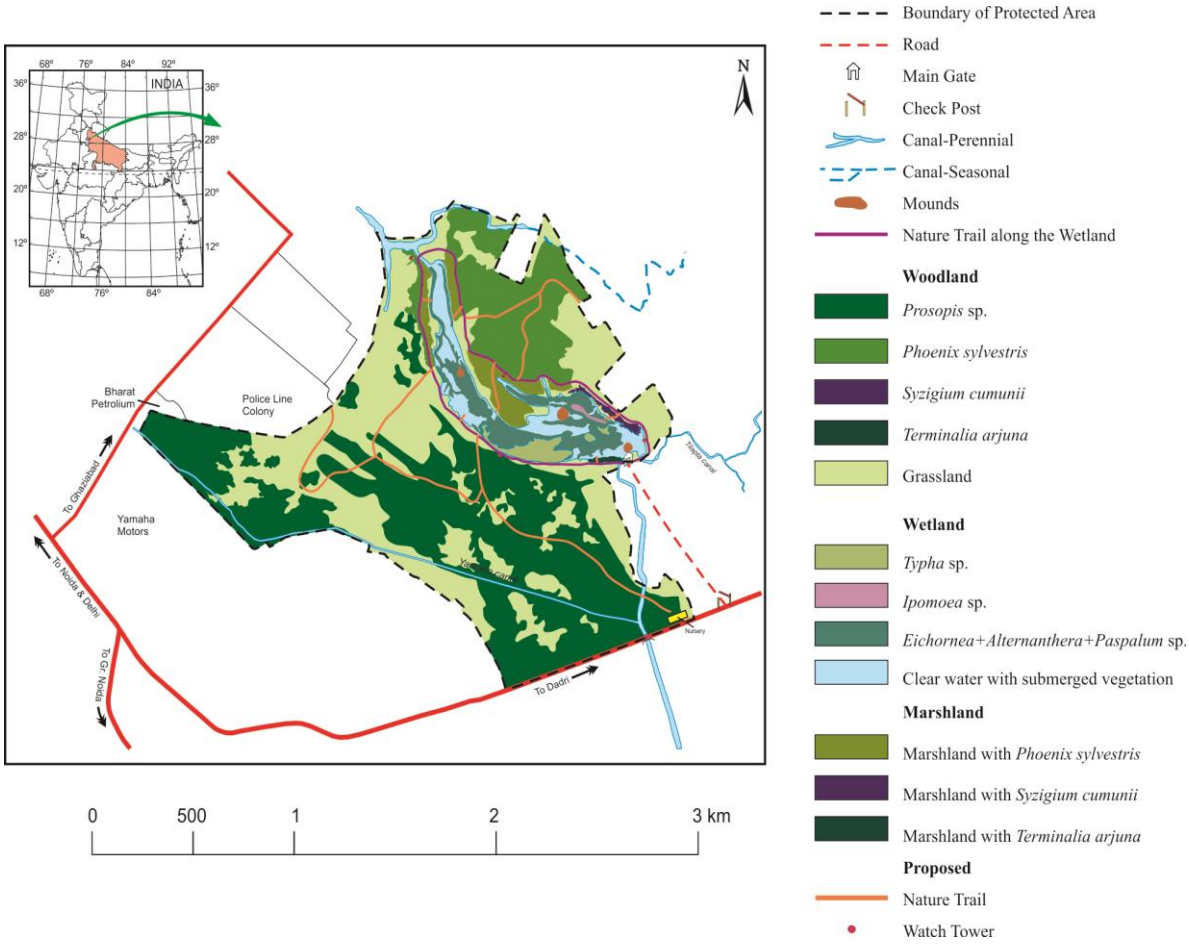

Figure 2. Micro-habitat map of Surajpur Reserve Forest.

Vegetation sampling was carried out in broadly classified habitats *i.e.* woodland, grassland and wetland by stratified random sampling. Terrestrial vegetation (woodland and grassland habitat) sampling was conducted in January - February 2012, while aquatic vegetation (wetland and marshland habitat) sampling was conducted in January - February 2013. In the woodland habitat, trees were sampled by placing circular plots of 10 m radius with an interval of 50 m. Shrubs were sampled within 3m radius while four 0.5 m × 0.5 m quadrats were laid for herbs and grasses in each plot. In all 52 plots were laid (4 plots in *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn, 8 plots in *Syzygium cumini* (L.) Skeels and 20 plots each in *Phoenix sylvestris* (L.) Roxb. and *Prosopis juliflora* (Sw.) DC. habitat, respectively). In the grassland habitat, grasses/sedges and herbs were sampled by placing 20 quadrats of 0.5 m × 0.5 m size and four quadrats of 0.5 m × 0.5 m were laid in each 10 m circular plot with an interval of 50 m distance.

Vegetation sampling for aquatic macrophytes was carried out by stratifying wetland area into 10 sampling blocks on the basis of water availability. Hydrophytic plants were further divided into 5 subtypes on the basis of their habitat and adaptation, Emergent (rooted erect herbs stand above the level of water), Rooted- floating (aquatic herbs floating or creeping), Submerged (rooted aquatic plants totally submerged in water), Free-floating (plants which are not rooted, their roots are suspended in water) and Amphibious (plants living partially in water

and partially above the surface of water) (Vijayan 1983). The abundance of these plant species was recorded by laying random sampling plots in each stratum. Quadrats of 0.5 m × 0.5 m were laid in each block with an interval of 5 m between two quadrats. In each sampling plot name of the plant species, number of individuals, water depth and percentage vegetation cover were recorded.

The data collected were compiled in MS-Excel software. Replicate data were pooled separately for individual sampling sites to compute estimates of population parameters. Overall mean density was estimated for respective habitats following Mueller-Dombois & Ellenberg (1974). Shannon Diversity Index and Margalef's Richness Index were used by DOS based Programme SPECDIVER.EXE programme (Ludwig & Reynolds 1988) for calculations of diversity and richness.

Plant Community Classification

PC-ORD (version 4.34) was used for classification of plant communities. Data were analysed by multivariate technique as Two Way Indicator Species Analysis (TWINSPAN), a computer based programme, commonly used for ecological studies (Hill 1979, Waite 2000). A thorough description about this method can be found in Dillon & Goldstein (1984). Plant community classification was done habitat-wise separately for all the three major habitats- woodland, grassland and wetland, respectively. The vegetation classification analysis was carried out using the polythetic divisive clustering technique in TWINSPAN (Siddiqui *et al.* 2010). The plant communities were classified and named into individual groups. This involved formation of groups of definite floristic composition and physiognomy. In the present analysis, uniform habitat condition was not taken into consideration. Five pseudo species cut levels (0, 2, 5, 10, and 20) were given according to the frequency of cover scale for all the habitats. The maximum level of divisions was 6, minimum group size for the division was 5 with the maximum number of indicators per division equal to 5. The total number of species and pseudo species calculated from TWINSPAN analysis. Relative Euclidean distance was measured and Nearest-neighbour linkage method (also called single linkage method) was adopted for cluster analysis (Hamid 2009). The homogenous groups were identified from the cluster made by TWINSPAN analysis and it has been done for plant community classification separately for terrestrial and aquatic habitats.

RESULTS

Habitat quantification

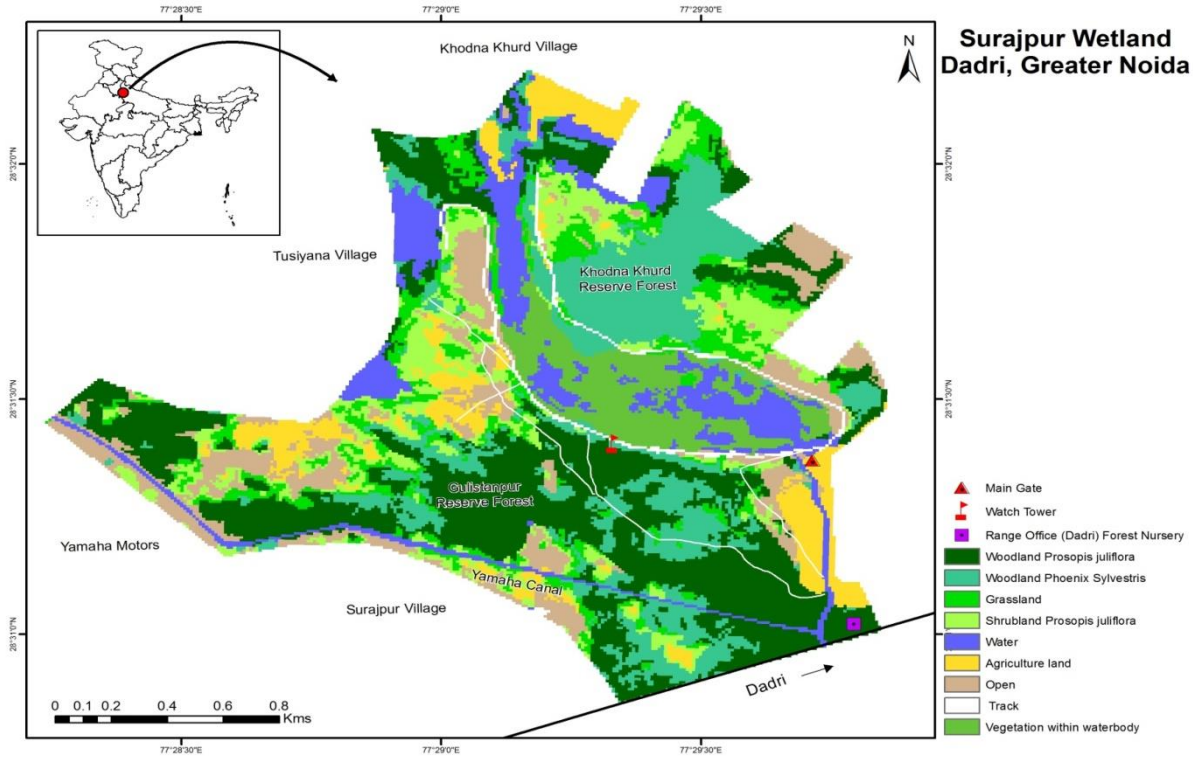

Figure 3. Mapping of various habitats of Surajpur Reserve Forest.

Different vegetation structures of the study area classified into three major habitats on the basis of dominant floristic composition and soil type as, woodland, grassland and wetland habitats (Fig. 3). These major habitats further divided into microhabitats, woodland includes *Phoenix sylvestris*, *Terminalia arjuna*, *Syzygium cumini*

and *Prosopis juliflora*, grassland are dominant with *Sachharum* sp., *Vetiveria zizanioides* (L.) Nash and *Desmostachya bipinnata* (L.) Stapf species, whereas wetland includes clear water with submerged aquatic vegetation of *Ceratophyllum demersum* L., *Hydrilla verticillata* (L.f.) Royle, *Vallisneria spiralis* L., emergent aquatic vegetation of *Eichhornia crassipes* (Mart.) Solms, *Alternanthera philoxeroides* (Mart.) Griseb., *Ipomoea* sp., *Typha angustata* Bory & Chaub., and marshland with *Phoenix sylvestris, Terminalia arjuna, Syzygium cumini* vegetation. The mosaics of habitat formed the 9 microhabitat types representing the woodland habitat as dominant habitat type and Nature trail (tracks) represents the minimum area of microhabitat (Table 1). The details of each microhabitat can be described as:

Table 1. Different habitat types in Surajpur reserve forest.

S.N.	Habitat types	Area (ha)	Percentage %)
1.	Woodland (*Prosopis juliflora*)	87.56	26.38
2.	Woodland (*Phoenix sylvestris*)	56.89	17.14
3.	Shrub-land (*Prosospis juliflora*)	33.40	10.06
4.	Grassland	27.91	08.41
5.	Water (Wetland area)	32.42	09.77
6.	Vegetation within water body (Marshy area)	31.94	09.62
7.	Open (Bare ground)	33.69	10.15
8.	Track (Nature trail)	04.19	01.26
	Total	**308.00**	**92.79**
9.	Agricultural land (outside Forest)	23.93	07.21

(i) *Woodland (Prosopis juliflora):* It is the most dominant microhabitat type (87.56 ha) in the study area, with 26.38% of the total area and reflects dark green colour with smooth texture. This microhabitat is found only in the Gulistanpur Reserve Forest area. It is distributed widely on the southern side around the water body. In the extreme western side of the reserve area, this habitat class can be seen as a dense patch.

(ii) *Woodland (Phoenix sylvestris):* It is the second most dominant microhabitat type (56.89 ha), with 17.14% of the total area in Khodna Khurd Reserve Forest area. This habitat class is represented by cyan colour in the map with smooth texture. It is distributed densely towards northern side and sparsely towards southern side intermixed with *Prosopis juliflora* woodland. The northern side of this microhabitat touches the wetland area.

(iii) *Shrub-land (Prosopis juliflora):* Shrub-land (other than trees) are the third most abundant microhabitat type (33.40 ha) in the study area representing 10.06% of the total area. It is represented with lightest green colour with course texture in map intermixed with *Prosopis juliflora* woodland. It is distributed mainly in the Gulistanpur Reserve Forest area followed by Khodna Khurd Reserve Forest area.

(iv) *Grassland:* This area (27.91 ha) is intermixed with woodland habitat and represents by 8.41% of the total area. This microhabitat type is shown by light green colour with course texture in the map, mostly towards the south western side of the area. This microhabitat type can be seen in Gulistanpur Reserve Forest and Khodna Khurd Reserve Forest blocks respectively.

(v) *Water (wetland area):* This is one of the major habitat types in the study area and account for about 19.39% (64.36 ha) of the total forest cover, including marshy area i.e. vegetation within water body. The wetland area is demarcated by a white coloured nature track with blue and green colour, as smooth texture in the map. This forest cover type falls in both Gulistanpur Reserve Forest and Khodna Khurd Reserve Forest blocks.

(vi) *Marshy Area (Vegetation within water body):* Small woodland patches of *Terminalia arjuna* along the south-eastern side and *Syzygium cumini* along the north-eastern side are located with respect to the wetland serves as marshland. The blue colour also represents the Yamaha canal which is passing through the Gulistanpur Reserve Forest along the *Prosopis juliflora* woodland microhabitat type.

(vii) *Open (bare ground):* The areas devoid of vegetation are depicted as open or bare ground. This microhabitat class is distributed towards the periphery and the area is represented by 10.15% (33.69 ha) of the total area. It is shown by light pink colour with course texture in the map.

(viii) *Nature Trail (Track):* There are 3 nature trails made passing through all the major habitats. The nature trail also serves as embankment to the wetland area. The complete nature trail includes the 1.26% of the total area (4.19 ha) and is depicted by white colour in map.

(ix) *Agriculture land:* This area lies outside, adjacent to the forest and is 7.21% of the total area (23.93 ha). The agriculture land belongs to Khodna Village Panchayat towards northern side of the forest and is depicted by yellow colour in map.

Vegetation structure and composition

During the study period, a total of 257 vascular plant taxa pertaining to 214 genera belonging to 29 orders and 65 families were recorded. During the study period, a comprehensive herbarium of 267 plant specimens including 229 plant species was prepared and arranged family-wise alphabetically from Acanthaceae to Zygophyllaceae, indexed in 09 herbarium files and was deposited at Department of Forestry and Environmental Sciences, Kumaun University, Nainital, Uttarakhand, India for future use. The analysis of flora shows a comparatively higher representation of herbaceous species (144) followed by 39 trees, 31 grasses, 20 climbers, 12 shrubs and 11 species of sedges during the study period (Table 2). The occurrence status of plant species recorded as Abundant by 51% (n= 130 plant species), followed by Frequent 19% (n= 50 plant species), Occasional as 16% (n= 42 plant species) and Rare as 14% (n= 35 plant species) of the total recorded plant species.

Table 2. Plant species composition in different taxonomic groups and in various life forms.

Habit	Angiosperms		Pteridophytes	Total
	Dicotyledons	Monocotyledons		
Trees	38	1	0	39
Shrubs	12	0	0	12
Climbers	20	0	0	20
Herbs	129	12	3	144
Grasses and Sedges	0	42	0	42
Total	**199**	**55**	**3**	**257**

Habitat association of each plant species was recorded. Woodland habitat recorded maximum of 157 plant species followed by 73 plant species in grassland habitat and 65 plant species in wetland habitat. The aquatic plant species found in wetland habitat was further classified into 5 subtypes on the basis of their nature of occurrence as amphibious (26 species), emergent (25 species), rooted-floating (6 species), submerged (4 species) and free-floating (4 species). The flowering and fruiting period of the plant species recorded for all seasons. Monsoon recorded maximum plant species (177 plant species), followed by summer (87 plant species) and winters (74 plant species) in the flowering and fruiting period.

The overall mean tree density in woodland habitat was determined as 76.52 individual ha^{-1}, however maximum tree density was recorded for *Phoenix sylvestris* (129.95 individual ha^{-1}) while *Terminalia arjuna* recorded least tree density (36.73 individual ha^{-1}) (Table 3). Overall mean shrub density in woodland habitat was determined as 219.69 individual ha^{-1}, wherein maximum density (769.23 individual ha^{-1}) was determined for *Ziziphus jujuba* Mill. and least density (20.40 individual ha^{-1}) was determined for *Abutilon indicum* (L.) Sweet (Table 3).

Table 3. Trees and Shrub density (individual ha-^{1}) in woodland habitat.

S.N.	Tree Species	Individual (ha^{-1})
1.	*Phoenix Sylvestris* (L.) Roxb.	129.77
2.	*Prosopis juliflora* (Sw.) DC.	72.84
3.	*Syzygium cumini* (L.) Skeels	66.72
4.	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	36.73
	Mean Density ha^{-1}	**76.52**
S.N.	**Shrub/Seedling/Sapling species**	**Individual (ha^{-1})**
1.	*Abutilon indicum* (L.) Sweet	20.40
2.	*Acacia nilotica* (L.) Delile	34.01
3.	*Phyllanthus reticulatus* Poir.	54.41
4.	*Phoenix sylvestris* (L.) Roxb.	163.24
5.	*Prosopis juliflora* (Sw.) DC.	476.10
6.	*Syzygium cumini* (L.) Skeels	20.40
7.	*Ziziphus jujuba* Mill.	769.23
	Mean Density ha^{-1}	**219.69**

Overall mean herb density in woodland habitat was determined as 0.50 individual m^{-2}, wherein maximum herb density (2.00 individual m^{-2}) was determined for *Alternanthera* sp. and least density (0.02 individual m^{-2}) was determined for *Achyranthes aspera* L. (Table 4). Overall mean grass/sedge density in woodland habitat was determined as 5.31 individual m^{-2}, wherein maximum grass/sedge density (30.71 individual m^{-2}) was determined for *Desmostachya bipinnata* (L.) Stapf and least density (0.04 individual m^{-2}) was determined for *Echinochloa crusgalli* (L.) P. Beauv. and *Eleocharis* species (Table 5).

Table 4. Herb density (individual m^{-2}) in woodland habitat.

S.N.	Herbs species	Individual (m^{-2})
1.	*Achyranthes aspera* L.	0.02
2.	*Ageratum conyzoides* (L.) L.	0.27
3.	*Alternanthera* sp.	2.00
4.	*Cannabis sativa* L.	0.15
5.	*Chenopodium* sp.	0.69
6.	*Ipomoea* sp.	0.04
7.	*Launaea nudicaulis* (L.) Hook.f.	0.17
8.	*Marsilea quadrifolia* L.	0.35
9.	*Dicliptera paniculata* (Forssk.) I.Darbysh.	0.04
10.	*Polygonum* sp.	0.54
11.	*Ranunculus sceleratus* L.	1.96
12.	*Rumex dentatus* L.	0.17
13.	*Sida* sp.	0.50
14.	*Solanum americanum* Mill.	0.04
15.	*Tridax procumbens* (L.) L.	0.08
16.	*Urena lobata* L.	0.12
17.	*Veronica anagallis-aquatica* L.	1.29
	Mean Density m^{-2}	**0.50**

Table 5. Grass/Sedge density (individual m^{-2}) in woodland and grassland habitat.

S.N.	Grass/Sedge species	Individual (m^{-2})
Woodland Habitat		
1.	*Cynodon dactylon* (L.) Pers.	12.92
2.	*Cyperus* sp.	2.88
3.	*Desmostachya bipinnata* (L.) Stapf	30.71
4.	*Echinochloa crus-galli* (L.) P.Beauv.	0.04
5.	*Eleocharis* sp.	0.04
6.	*Imperata cylindrica* (L.) Raeusch.	1.00
7.	*Paspalum distichum* L.	2.12
8.	*Saccharum ravennae* (L.) L.	0.48
9.	*Sporobolus diandrus* (Retz.) P.Beauv.	1.10
10.	*Chrysopogon zizanioides* (L.) Roberty	1.81
	Mean Density m^{-2}	**5.31**
Grassland Habitat		
1.	*Chrysopogon zizanioides* (L.) Roberty	3.00
2.	*Cynodon dactylon* (L.) Pers.	6.61
3.	*Desmostachya bipinnata* (L.) Stapf	19.25
4.	*Saccharum ravennae* (L.) L.	0.38
5.	*Sporobolus diandrus* (Retz.) P.Beauv.	0.50
	Mean Density m^{-2}	**5.90**

The overall mean grass/sedge density in grassland habitat was determined as 5.90 individual m^{-2}, wherein maximum density (19.27 individual m^{-2}) was determined for *Desmostachya bipinnata* and least density (0.38 individual m^{-2}) was determined for *Saccharum ravennae* (L.) L. Only one species of herb *i.e. Chenopodium album* L. was recorded in the grassland habitat, the density of which was determined as 1.6 individual m^{-2} (Table 5).

The overall mean herbs, grasses and sedge density in wetland habitat was determined as 9.92 individual m^{-2}, wherein maximum density (38.20 individual m^{-2}) was determined for *Alternanthera philoxeroides* and least density (0.08 individual m^{-2}) was determined for *Ceratophyllum demersum* and *Ranunculus sceleratus* L. (Table 6).

Among three habitats, woodland habitat represents the maximum Margalef's species richness (4.72) and Shannon-Weiner's diversity index (0.98) and grassland habitat represents minimum Margalef's species richness (0.80) and Shannon-Weiner's diversity index (0.40). Whereas wetland habitat represents median values for both the indices (Table 7).

Plant Community Classification

TWINSPAN analysis was done for plant community classification. The analysis was made separately for terrestrial and aquatic habitats, woodland-grassland and wetland habitat, respectively.

Table 6. Aquatic herbs, grasses and Sedge density (individual m^{-2}) in wetland habitat.

S.N.	Aquatic herbs and grasses	Individual (m^{-2})
1.	*Alternanthera philoxeroides* (Mart.) Griseb.	38.20
2.	*Azolla caroliniana* Willd.	12.75
3.	*Ceratophyllum demersum* L.	0.08
4.	*Cynodon dactylon* (L.) Pers.	0.12
5.	*Eichhornia crassipes* (Mart.) Solms	14.88
6.	*Hydrilla verticillata* (L.f.) Royle	0.28
7.	*Ipomoea aquatica* Forssk.	0.12
8.	*Marsilea quadrifolia* L.	3.16
9.	*Paspalum distichum* L.	35.32
10.	*Ranunculus sceleratus* L.	0.08
11.	*Spirodela polyrrhiza* (L.) Schleid.	21.28
12.	*Typha domingensis* Pers.	0.88
13.	*Utricularia stellaris* L.f.	1.76
	Mean Density m^{-2}	**9.92**

Table 7. Diversity Indices for different habitats in the Surajpur wetland.

Habitat	No. of Species	Diversity Indices	
		Margalef's Richness (S)	Shannon Diversity (H´)
Woodland	40	4.72	0.98
Grassland	6	0.80	0.40
Wetland	13	1.50	0.75

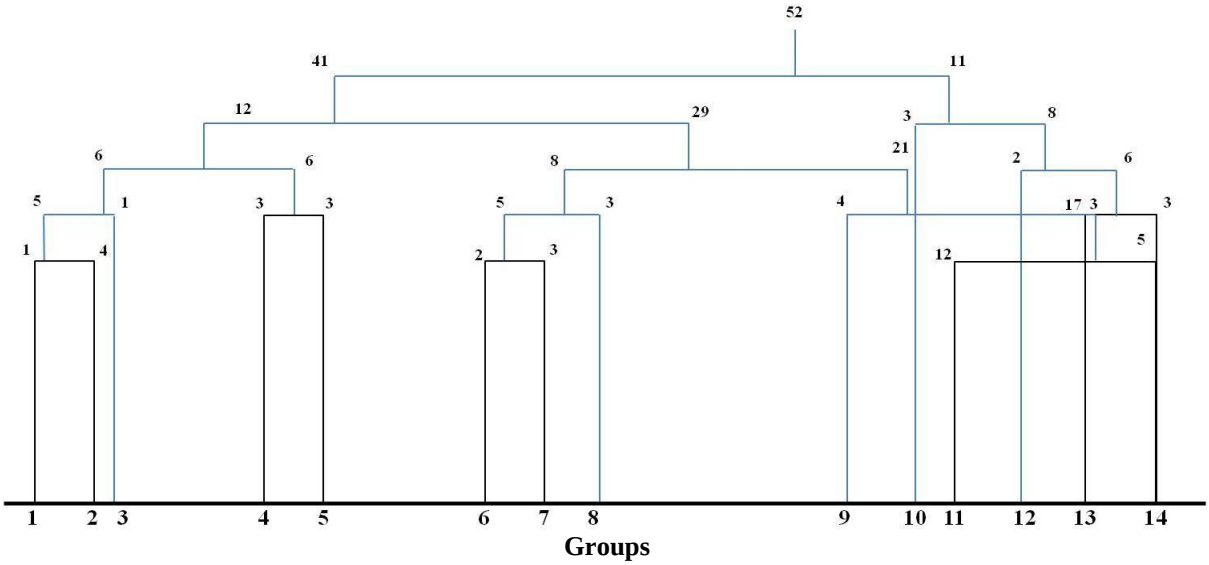

Figure 4. Cluster dendrogram by TWINSPAN analysis in woodland habitat.

In the terrestrial habitats, a total of 52 sampling plots were laid- 4 plots in *Terminalia arjuna*, 8 plots in *Syzygium cumini* and 20 plots each in *Phoenix sylvestris* and *Prosopis juliflora* habitats respectively. A total of 34 plant species comprising trees, shrubs, climbers, herbs, grasses and sedges recorded in all the 52 sampling plots were pooled together for TWINSPAN analysis. The total number of species and pseudo species is 115. The application of TWINSPAN technique made it possible to divide the set of 52 sampling plots inside the woodland habitat into 14 clusters/groups at level 6 of the hierarchical classification (Fig. 4). The first TWINSPAN dichotomy of Hierarchical classification separated all the 52 plots into two clusters, that in the left direction exists 41 plots with *Desmostachya bipinnata* as indicator species where as in right direction exists 11 plots with *Cyperus* sp. as indicator species. The second division, 41 plots have divided into two clusters that in left direction exists 12 plots with *Prosopis juliflora* as indicator species and right direction exists 29 plots with *Desmostachya bipinnata* as indicator species. The third division, 11 plots have divided into two clusters that in left direction exists 3 plots with *Terminalia arjuna* as indicator species and right direction exists 8 plots with *Cyperus* sp. and *Paspalum distichum* L. as indicator species. The fourth division, 12 plots have divided into two clusters of 6 left and 6 right directions with *Prosopis juliflora* as indicator species. The fifth division, 29 plots have divided into two clusters that in left direction 8 plots with *Cynodon dactylon* (L.) Pers. and *Prosopis juliflora* as indicator species and right direction exists 21 plots with *Desmostachya bipinnata*, *Cynodon dactylon*

and *Phoenix sylvestris* as indicator species. The sixth division, 8 plots have divided into two clusters that in left direction two plots with *Paspalum distichum* as indicator species and right direction exists 6 plots with *Ranunculus scleratus* and *Sizigium cumini* as indicator species (Table 8). Thus by applying TWINSPAN analysis technique, five homogenous groups have been identified representing five plant communities in woodland habitat (Table 9).

Table 8. TWINSPAN classification of plant species in woodland habitat.

Main groups	I	II	III	IV	V	
Plot numbers **Species code**	444554 869017	334333 391456	5444334 1202578	2224111112222223112 33 4789336789013456145202	11 1 23402589671	
19 Phoe syl	------	----1-	2-12-2--	413-13355544323413323	1-22-121---	000
2 Acac sp	------	------	-------	----------3------	----------	00100
12 Eleo sp	------	------	-------	----------2-------	----------	00100
24 Sach sp	------	------	-------	----2----12----2-3--3	----------	00100
33 Viti ziz	------	------	------4	----21-1--3--2-34-523	----------	00100
1 Abut ind	------	------	-----2-	----------	----------	00101
10 Desm bip	2----1	---423	--44-445	55555533255555-5555553	----------	00101
34 Zizi sp	------	------	-----1--	----------	----------	00101
8 Cyno dac	--12-4	--1---	35444---	-14-545555555555--3-4	-3-42------	0011
4 Ager con	------	---3--	---2--3-	----------	----------	0100
3 Achy asp	------	---1--	-------	----------	----------	01010
18 Peri pen	-1----	1-----	-------	----------	----------	01010
25 Sida sp	-1----	4-2232	-----1-	----------	--1-------	01010
31 Uren lob	------	----22	----1--	----------	----------	01010
27 Spor dia	-----5	2231-2	--4----	----------	----------	01011
21 Pros jul	344443	312213	33344333	2122---------2-------	42-32212-1-	011
6 Cann sat	------	------	-------	----------	-3---------	10
14 Kirg ret	------	------	-------	----------	-13--------	10
26 Sola nig	------	------	-------	----------	2----------	10
29 Term arj	------	------4	-------	----------	444--------	10
7 Chen sp	--2---	-------	--2----	----------	---44--222-	1100
11 Echi cru	------	------	-------	----------	---2-------	1100
5 Alte phi	------	------	-------	----34----------	---24532154	11010
16 Mars qua	------	------	-------	----------	----43-----	11010
17 Pasp dis	------	------	-------	---------2----------	22-45534322	11010
30 Trid pro	------	------	-------	----------	---2-----2-	11010
22 Ranu scl	------	------	-------	----------	---134-2555	110110
23 Rume den	------	------	-------	----------	----13-----	110110
28 Syzi cum	------	------	-------	----------	---44444444	110110
13 Ipom sp	------	------	-------	----------	---------2	110111
20 Poly sp	------	------	-------	----------	-----323332	110111
32 Vero ana	------	------	-------	----------	----142-513	110111
9 Cype sp	------	------33	-------	----------3---------	24425545233	111
15 Laun pro	------	------	-------	----------	2------3---	111
Groups code	000000 000000 000000 000001 01111	000000 000000 111111 000111	00000000 11111111 00000000 00000111 00111	0000000000000000000 1111111111111111111 1111111111111111111 0000111111111111111 00000000000011111	11111111111 00011111111 00111111 000111	

In the aquatic area, wetland habitat, a total of 100 quadrats were laid in 10 blocks (10 quadrats in each block). Out of the 100 quadrats, only 67 quadrats recorded plant species. Therefore, only 67 quadrats are considered for TWINSPAN plant community classification. A total of 11 plant species (aquatic herb species) recorded in all the 67 sampling quadrats were pooled together for TWINSPAN analysis. The total number of species and pseudo species is 41. The application of TWINSPAN technique made it possible to divide the set of 67 sampling quadrats inside the wetland habitat into 8 clusters/groups at level 6 of the hierarchical classification (Fig. 5). The first TWINSPAN dichotomy of Hierarchical classification separated all the 67 plots into two clusters, that in the left direction exists 65 quadrats with *Alternanthera philoxeroides* as indicator species

whereas in right direction exists only 2 quadrats with *Hydrila verticillata* as indicator species. The second division, 65 quadrats have divided into two clusters that in left direction exists 17 quadrats with *Mersilea quadrifolia* L. as indicator species and right direction exists 48 quadrats with *Eichornea crassipes* and *Alternanthera philoxeroides* as indicator species. The third division, 17 quadrats have divided into two clusters, which in left direction two quadrats with *Typha domingensis* Pers. as indicator species and in right directions exists 15 quadrats with *Marsilea quadrifolia* as indicator species. The fourth division, 48 quadrats have divided into two clusters of that is in left direction 28 quadrats with *Alternanthera philoxeroides* as indicator species whereas in the right direction exists 20 quadrats with *Spirodela polyrrhiza* (L.) Schleid. and *Eichornea crassipes* as indicator species (Table 10). Thus by applying TWINSPAN analysis technique, three homogenous groups have been identified representing three plant communities in wetland habitat (Table 11).

Table 9. Plant communities identified by TWINSPAN analysis in woodland habitat.

S.N.	Dominant plant community	Associated plant species	Plots number in which species reported
1.	*Prosopis* community	*Desmostachya bipinnata*, *Cynodon dactylon*, *Chenopodium* sp., *Dicliptera paniculata*, *Sida* sp.	48, 46, 49, 50, 51 and 47
2.	*Prosopis-Sida* community	*Sporobolus diander*, *Desmostachya bipinnata*, *Urena lobata*, *Dicliptera paniculata*, *Achyranthes aspera*, *Ageratum conizoides* and *Cynodon dactylon*	33, 39, 41, 34, 35 and 36
3.	*Desmostachya–Cynodon* community	*Prosopis juliflora*, *Phoenix sylvestris*, *Terminalia arjuna*, *Chrysopogon zizanioides*, *Abutilon indicum*, *Ziziphus* sp., *Ageratum conizoides*, *Sida* sp., *Urena lobata*, *Sporobolus dianadrus*, *Chenopodium* sp., and *Cyperus* sp.	01, 52, 40, 42, 45, 37, 38 and 44
4.	*Desmostachya–Cynodon-Phoenix* community	*Chrysopogon zizanioides*, *Sachharum sp.*, *Alternanthera philoxeroides*, *Prosopis juliflora*, *Acacia sp.*, *Eleocharis* sp., *Paspalum distichum* and *Cyperus* sp.	27, 28, 29, 43, 3, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 31, 14, 15, 22, 30 and 32
5.	*Cyperus-Paspalum-Syzygium* community	*Terminalia arjuna*, *Alternanthera philoxeroides*, *Paspalum distichum*, *Ranunculus scleratus*, *Prosopis juliflora*, *Phoenix sylvestris*, *Cynodon dactylon*, *Cannabis sativa*, *Phyllanthus reticulatus*, *Chenopodium* sp., *Marsilea quadrifolia*, *Veronica anagallis-aquatica*, *Polygonum* sp., *Launea procumbens*, *Sida* sp., *Solanum nigrum*, *Echinochloa crus-galii*, *Tridex procumbens*, *Rumex dentatus* and *Ipomoea* sp.	02, 03, 04, 10, 12, 05, 08, 09, 06, 07 and 11

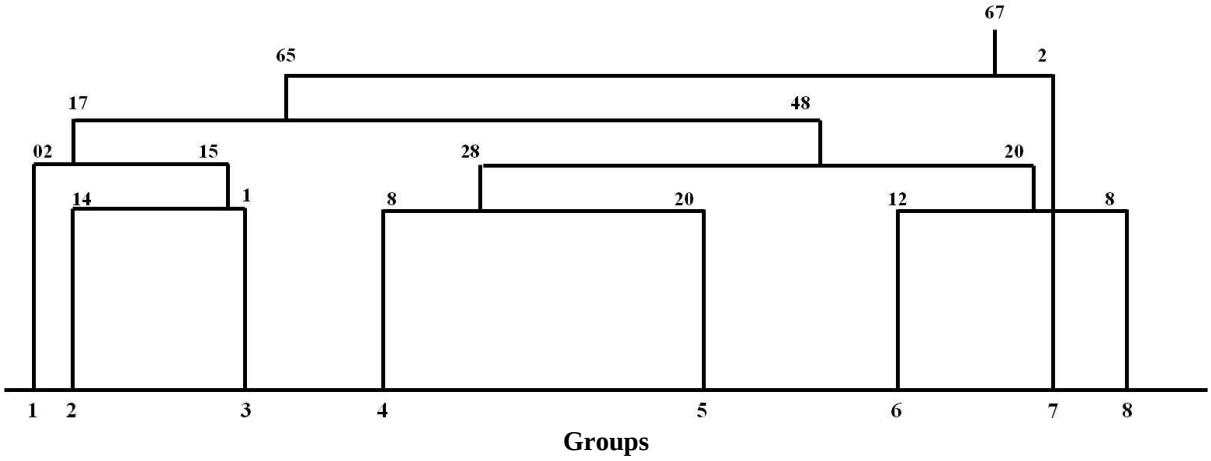

Figure 5. Cluster dendrogram by TWINSPAN analysis in wetland habitat.

DISCUSSION

Vegetation play an important role for the existence of various biodiversity and wildlife especially avian fauna in an area as it provides the suitable habitat for survival. Surajpur wetland is also one such habitat, of which vegetation structure forms the integral part of wildlife habitat in the area and is pre-requisite for the better ecological understanding and management of the area. The different varieties of vegetation provide favorable habitat conditions to survive the avian fauna in the study area.

Table 10. TWINSPAN classification of plant species in wetland habitat.

Main groups	I	II	III	
Plot numbers Species code	4544445555666666322223456 3767890456012345234788116134567901231479024592	1111333344445 8456789012563562387 90	11111122222333555623 90	
5 Hydr ver	----------	----------	----------32	1
11 Utri ste	----------22252	----------22---------		01
10 Typh aun	3----------2	----------323----------		01
7 Mars qua	21223222232222224	2-3--322----------	----------	01
6 Ipom sp	2----------	----------	----------	01
9 Spir pol	-2----------2	3-2----------2-5	-4-555-55533------2--	001
8 Ranu scl	----------	----------	------2----------	001
4 Eich cra	---2-2-1-1------2	-22--2-15454-----2---2-23-2-	4255445554-221222213--	001
2 Azol pin	----------	----------5----------	---5---555-43------2--	001
3 Cera dem	----------2	----------	----------	000
1 Alte phi	----------2	24222233444555525252422234423	-44----45-35------2--	000
Groups code	00000000000000000 00000000000000000 00111111111111111 0000000000000	00000000000000000000000000000 11111111111111111111111111111 00000000000000000000000000000 0000000000000000000111111111111111111110	00000000000000000011 11111111111111111111 11111111111111111111 00000000000 0	

Surajpur wetland revealed a total of 257 vascular plants that represents about 47% of the total NCR flora (Maheshwari 1963) and 10% of the total Uttar Pradesh flora (Srivastav 2004) respectively. High diversity of vascular plants in the region is mainly attributed to climatic, topographic and edaphic factors. Similar floristic studies were also conducted in Indian region, Manral *et al.* (2013) reported 192 plant species in Okhla Bird Sanctuary in Noida, NCR, Chaudhary *et al.* (2012) reported 95 species only from Poaceae and Cyperaceae family in Noida, NCR, Mishra & Narain (2010) reported 129 plant species in Bakhira wetland Uttar Pradesh, Adhikari & Babu (2008) reported 178 plant species in Baanganaga wetland, Uttarakhand.

The outcome of habitat mapping includes eight microhabitat types with the maximum area of *Prosopis juliflora* woodland (26.38% of the total area) and an additional land cover type, *i.e.* agricultural land (7.21%) outside the protected area serves as buffer of the reserve forest area. *Prosopis juliflora* is a fast-growing, nitrogen-fixing and tolerant to arid conditions, saline soils (Mwangi & Swallow 2005) and has a deep to very deep, well-meshed root system. It can grow in adverse climatic conditions also. It is also not palatable to livestock and does not require any proper maintenance to sustain. Large-scale plantation work can be undertaken on such habitats without any fencing.

Out of three major habitats (woodland, grassland and wetland), woodland recorded the maximum number of plant species (157 plant species). Ecologically it is very good for wildlife, as it serves as a refuge for threatened faunal diversity. It is particularly important for conserving declining woodland birds that are found in the region, including the Greater Spotted Eagle (*Clanga clanga* Pallas, 1811), Steppe Eagle (*Aquila nipalensis* Hodgson, 1833), Orange-headed Thrush (*Geokichla citrine* Latham, 1790), Black-rumped Flamback (*Dinopium benghalense* L., 1758), Brown-headed Barbet (*Megalaima zeylanica* Gmelin, 1788), Eurasian Golden Oriole (*Oriolus kundoo* Sykes, 1832), Rufous Treepie (*Dendrocitta vagabunda* Latham, 1790) and Red Collared-dove (*Streptopelia tranquebarica* Hermann, 1804). These are resident birds and prefer woodland habitat for nesting and roosting in Surajpur wetland.

The species richness of different life forms, such as trees, shrubs and herbs, is one of the major considerations in recognizing the importance of an area for conservation (Negi *et al.* 2008). The various life forms are the constituents of the various habitats, that attracts many wildlife species specially birds and insects. Margalef's species richness index and Shannon-Weiner's diversity index recorded maximum for woodland habitat and least for grassland habitat due to larger area occupied by woodland habitat (43.52% of the total area) and less area occupied by grassland habitat (8.41% of the total area). Different life forms such as trees, shrubs and herbs have different diversity patterns (Grubb 1977). Out of total 257 plant species, maximum number herbs species (144 plants) recorded, which has clearly indicates that the marshy land habitat supporting rich herb diversity. The difference in species diversity between communities generally results from variation in site

quality (Denslow 1980). Pant & Samant (2007) reported that high richness may be due to diverse habitats and suitable edaphic and climatic factors supporting growth and survival of the species. As Surajpur wetland also showing high species richness due to the mosaic of habitats and suitable climatic factors that enhances the growth and survival of species. The monsoon season, recorded maximum plants in flowering stage (177 plants), because of higher soil moisture content (Bajpai *et al*. 2017), which results high humic acid and organic content as well as low temperature in the soil. On the other hand, the minimum value in summer season indicates higher heterogeneity in climatic conditions which results poor plant growth (Patel & Pandya 2014).

Table 11. Plant communities identified by TWINSPAN analysis in wetland habitat.

S.N.	Plant communities	Associated plant species	Plots no. in which species reported
1.	*Marsilea* community	*Typha aungustata*, *Eichornea crassipes*, *Utricularia stellaris*, *Ipomoea* sp. and *Spirodela polyrriza*	43, 57, 46, 47, 48, 49, 50, 54, 55, 56, 60, 61, 62, 63, 64, 65 and 32
2.	*Alternanthera* community	*Eichornea crassipes*, *Utricularia stellaris*, *Typha domingensis*, *Marsilea quadrifolia*, *Spiroldela polyrriza*, *Azolla pinnata* and *Ceratophyllum demersum*	32, 24, 27, 28, 38, 41, 51, 66, 01, 03, 04, 05, 06, 07, 09, 10, 11, 12, 13, 31, 34, 37, 39, 40, 42, 44, 45 and 59
3.	*Eichornea-Spirodela* community	*Azolla pinnata*, *Alternanthera philoxeroides*, *Hydrila verticillata*, *Utricularia stellaris* and *Ranunculus scleratus*	02, 08, 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26, 33, 35, 63, 52, 53, 58, 67, 29 and 30

In woodland habitat, *Terminalia arjuna* recorded maximum tree density while *Prosopis juliflora* recorded least density because *Terminalia arjuna* was densely planted only at one place that is on the edge of water body, whereas *Prosopis juliflora* was grown naturally and sparsely in the entire southern range of the study area. Among shrub species in woodland habitat, *Ziziphus jujuba* recorded maximum density and *Abutilon indicum* was determined least density, because *Ziziphus jujuba* is a fast growing shrub species and can flourish even in very extreme temperatures and thrives under rather dry conditions (Orwa *et al.* 2009). Among herb species in the woodland habitat, *Alternanthera* sp. recorded maximum density and *Achyranthes aspera* recorded least density because *Alternanthera* sp. is a moisture loving species and ground cover was wet during sampling that enhanced the growth of this species in comparison to *Achyranthes aspera*, as it is a herb species which grows mostly in dry areas.

Among grass species, *Desmostachya bipinnata* is dominating in both the habitats i.e. woodland and grassland, as this grass species is a drought and salt-tolerant C4 grass of desert or semi-desert conditions with a deep, strong rhizome, making it an excellent sand-binder (Pandey *et al.* 2013). Though the study area falls in the upper Gangetic plain, it shows similarities with semi-arid region, because it is very close to Delhi, which is a semi-arid region. Grassland habitat is very important in terms of providing shelter for threatened faunal biodiversity especially grassland birds, including Bristled Grassbird (*Chaetornis striata* Jerdon, 1841), Black Francolin (*Francolinus francolinus* L., 1766), Crested Lark (*Galerida cristata* L., 1758), Booted Warbler (*Iduna caligata* M.H.C. Lichtenstein, 1823), Ashy Prinia (*Prinia socialis* Sykes 1832) and Zitting Cisticola (*Cisticola juncidis* Rafinesque, 1810).

Invasive plants are widely recognised as one of the most important threats to native plant biodiversity (Kolar & Lodge 2001). Surajpur wetland is a marshland type habitat supported mostly amphibious and emergent category of aquatic herbs. Excessive growth of herbaceous weed such as *Alternanthera philoxeroides* and *Eichhornea crassipes* are issues of concern in wetland habitat. This weed becomes a growing menace in water bodies in India (Varshney *et al.* 2008). These both the plants are very harmful invasive, exotic and obnoxious weeds reported across the world by many workers (Bassett 2008, Ruiz *et. al.* 2008, Mandal & Mondal 2011, Bassett *et al.* 2012, Chen *et al.* 2013, Chatterjee & Dewanji 2014).

Plant communities are defined as the collection of plant species growing together in a particular location that show a definite association with each other (Mueller-Dombois & Ellenberg 1974). The species in a community grow together in a particular environment because they have a similar requirement for existence in terms of environmental factors such as light, temperature, water drainage and soil nutrients (Billings 1974, Mueller-Dombois & Ellenberg 1974, MacAlister 1997).

To know the details of various plant species enumerating in the various habitats, TWINSPAN analysis was performed and dominant plant communities were identified habitat wise separately. In TWINSPAN analysis,

five plant communities were identified in terrestrial habitat, *Prosopis* community, *Prosopis-Sida* community, *Desmostachya–Cynodon* community, *Desmostachya–Cynodon-Phoenix* community and *Cyperus-Paspalum-Syzygium* community, and three plant communities were identified in aquatic habitat, *Marsilea* community, *Alternanthera* community and *Eichornea-Spirodela* community. Thus, with the help of TWINSPAN analysis, we can come to know what are the various plant communities existing in the various habitats. Subsequently, the analysis helps in planning for protections and conservation measures of prevailing wildlife faunal diversity.

The diverse floral composition and the better management practices have made the site a safe haven for particularly waterbirds in the region. The excessive growth of *Eichhornia crassipes* and *Alternanthera philoxeroides* are issues of concern and appropriate measures have been implemented to check their growth. As the hydrological system is the major factor to control the plant composition of Surajpur wetland, the management of natural flooding is required to ensure the sustenance of mosaic of habitats.

CONCLUSION

The present study concludes that the Surajpur Reserve Forest represents mosaic of habitats supports rich avifauna and other biodiversity. The record of 13 species of mammals (Ansari 2017a), 186 species of avifauna (Ansari & Nawab 2015, Ansari 2017b), 19 species of herpetofauna (Ansari 2018a), 15 species of fishes (Ansari 2018b), 53 species of butterflies (Ansari *et al.* 2015) and 36 species of odonates (Ansari 2017c) from Surajpur wetland ecosystem corroborates the fact. Surajpur area is very important to biodiversity conservation as it provides an opportunity to conserve and preserve the native flora, fauna and biodiversity amidst a densely populated urban area without hindering the development of social and economical structures. There is a need to monitor these habitats for long-term protection and conservation of various groups of flora and fauna in the area. The present findings can be used as a baseline for future studies and a comparison with previous works suggests that steps should be taken to curtail the growth of invasive species and plantation of native species should be encouraged. Appropriate measures need to be taken to check the growth of invasive species. The diverse floral composition and the better management practices have made the site a safe haven for particularly waterbirds in the region. As the hydrological system is the major factor to control the plant composition, the maintenance of natural flooding is required for sustenance of mosaic of habitats at Surajpur. The urban and industrial development across the Greater Noida city which is resulting in habitat destruction is a matter of great concern. This small piece of marshy land with stagnant water has very rich biodiversity creating a small biodiversity hotspot. This area should therefore be conserved and kept pollution free across the city limits as they support a good congregation of aquatic/semi aquatic insects.

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