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Urban Biodiversity and Green Spaces in Delhi: A Case Study of New Settlement and Lutyens' Delhi

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ABSTRACT The paper presents a comparative scenario of green space planning in Lutyens' Delhi, an old colonial area, with the Dwarka sub-city of Delhi. A mixed methods approach using field based surveys and questionnaires for randomly selected residential areas, parks and roads was employed to understand the urban tree species distribution, its planning and management practices and the people's perception regarding urban forestry. Urban trees encountered in Lutyens' Delhi appeared quite diverse, with 125 species as compared to 26 species in Dwarka. In Dwarka, *shisham* (*Dalbergia sissoo*) and *jamun* (*Sygizium cumini*) together constitute about three-fourth of the total population of the sampled avenue trees, whereas *neem* (*Azadirachta indica*) and *imli* (*Tamarindus indica*) constitute about half of the total sampled avenue trees in Lutyens' Delhi. Further, species selection is compromised in lieu of fast growing tree species. Though awareness related to benefits of urban trees was found high among sampled residents, low faunal biodiversity remains a bigger concern. Census and periodic monitoring of urban trees besides expansion of green spaces, while formulating infrastructure related policies can improve the urban forestry status of Delhi.

INTRODUCTION

Considering the extent of urban agglomerations, the National Capital Territory of Delhi stands as the world's second largest urban area with 25 million people (United Nations 2014). With increasing urbanization, huge quantities of vegetation are being replaced with concrete buildings and low albedo surfaces (Singh and Grover 2015), and since increasing urbanization is inevitable, the challenge is to live with it and its environmental impacts. Realizing the importance of urban trees environmentalists and urban designers throughout the world are working towards the concept of eco-cities. In India, however, the concept of urban forestry has not received much attention and therefore, a significant understanding of urban trees is essential followed by its implementation in the urban development process. The Forest Survey of India (FSI) 2013 reports urban tree cover area of India as 16.40 percent of its total urban area, and the Municipal Corporation of Delhi (MCD) reports Delhi to have 18,000 parks constituting twenty percent of green cover that is further planned to increase to thirty-three percent in coming years.

The role and benefits of urban green spaces are enormous. Hillary et al. (2002) describes biodiversity conservation as an important role played by the urban green spaces. The other critical ecosystem services provided by urban trees include air filtration, microclimate regulation, noise reduction, rainwater drainage, and sewage treatment (Bolund and Hunhammar 1999) besides recreational and cultural values. In metro cities and often in small towns, tree shade also acts as shop and provides shelter to the vendors and poor shopkeepers (Bhattacharya and Nigam 2010). Several studies on floral biodiversity and species richness have been carried out in different states of India, but it still lacks key attention on urban green spaces aspect. Recently emphasis has been put on to study the instrumental functions of urban forests, both internationally and nationally. Examples of such attempts include quantifying CO_2 sequestration by urban forests (McPherson and Simpson 1999), studies on air pollution reduction by urban trees (Nowak et al. 2006), studies on developing criteria to select tolerant plants for urban forests (Pandey et al. 2015) and studies on energy saving by trees

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(Akbari et al. 2001; Rosenfeld et al. 1998). Attempts have also been made to study the potential of trees in carbon sequestration from urban areas in Pune (Warran and Patwardhan 2005) in Maharashtra, India (Chavan et al. 2010). Studies conducted in academic campuses of cities such as National Environmental Engineering Institute (NEERI) Campus, Nagpur (Gupta et al. 2008) and Indian Institute of Science Campus, Bangalore (Mhatre 2008) suggest the critical importance of understanding, designing, planning and management of urban green spaces. These studies highlight the need for focusing on non-forested but tree dominated areas such as university campus, including avenues and public gardens and their role in carbon sequestration.

According to Kuruneri-Chitepo and Shackleton (2011), with little information on the distribution, diversity and density of urban trees, particularly in the developing world where urbanization is most rapid, it becomes important to collect adequate data that represents the correct status of urban trees. A recent study in Bangalore, India, suggests that data on tree distribution, including species composition, size and age structure, and spatial inventories is essential to allow for more effective management of street trees and the biodiversity they represent (Nagendra and Gopal 2010). In many developing countries, the significant contribution of street trees towards urban biodiversity has been realized. But the forest managers neither have the necessary knowledge for appropriate species selection, care and maintenance (Chacalo et al. 1994) nor do they have complete information on street trees (Escobedo et al. 2006; Alvey 2006; Jim and Chen 2008). This is especially true of many Asian cities despite the fact that these constitute some of the most densely populated parts of the world (Jim and Chen 2008).

Lutyens' Delhi with its gardens and British time planted avenue trees represents the city's green center and is considered as a standard in terms of urban green space planning and management as compared to other areas within Delhi. The study primarily documents how the different land use patterns of old (Lutyens' Delhi) and new city (Dwarka sub-city) planning affect the kind of tree species it sustains.

Roads in Lutyens' Delhi tend to be dominated with high density of road traffic than Dwarka as most of the Delhi Government offices lay in New Delhi area. Dwarka on the other hand, is planned in a way to accommodate surplus population of 1 million by building residential societies that constitute 48.54 percent of the total land use distribution. Different sectors of Dwarka are connected by 60m and 45m wide roads, whereas within a sector different residential societies are connected by 30m wide roads (Dwarka Brochure 1997). Preferred species of trees are planted in parks and on roadsides by the Delhi Development Authority (DDA) that suit the local conditions. According to Nagendra and Gopal (2010), trees on roads with heavy road traffic would preferentially be those used for shade that is large canopied, tall trees, which would not require significant pruning. In contrast, trees on roads dominated with residential societies tend to be pruned more frequently as their branches present a hazard for overhead wires, pedestrians and houses adjacent to the road. Such roads would tend to have a greater proportion of flowering and fruiting trees. This underlines the basis for understanding the planning and management of two study areas by respective authorities, with special emphasis on species selection and maintenance of old and mature British time planted trees.

Objectives

This paper thus attempts to identify the differences and similarities between the distributions, planning and management practices of urban trees in two study areas followed by a residential survey. Such information can be of importance for city developers during the planning process as well as for policymakers, urban activists, students and educators who are willing to strive for maintaining and protecting the urban biodiversity.

Historical Review

Edwin Lutyens envisaged New Delhi as a 'Garden City' soon after the Raisina Hill was selected for building the new capital of India in 1911. In order to impart the feel of a garden, trees were planted along each avenue, to provide a soothing greenery to counteract Delhi's dry and dusty environment. Today's New Delhi's avenue plantation reflects the careful design and planning of Lutyens and Herbert Baker (NDMC brochure n.d.). Assisted by other town planners, foresters, and horticulturists, evergreen and drought-resistant trees were finally selected for plantation here. After much research and discussion a list of thirteen species of trees for avenue plantation was finalized. Of these, eight spe-

cies (including common Indian trees like the *jamun, neem, arjuna, peepal,* and tamarind) were the most commonly planted tree species. In addition, one imported species (the African sausage tree, *Kigelia africana*) was chosen for plantation (INTACH 2012).

Besides selecting the species to be planted, Lutyens and Mustoe planned the spacing of the trees along the avenues, how and where different species could be planted along a single stretch, and how trees could be grouped or spread out to best showcase the structures of New Delhi. The grandest trees were used along avenues leading to the major buildings, while lesser avenues, for instance, some in the 'bungalow zone' where officials had their residences, were lined with less imposing tree species. To maximize the effect of the 'Garden City', and to create continuity between one area and the next, the same tree species were often planted along roads that converged or intersected. Avenue plantation began in 1919-1920, with the last trees being planted approximately five years later. By the time the Secretariat and Government House were inaugurated, many of the trees had grown much as Lutyens and Mustoe had envisaged in their plans. Even today, 104 years later, the British initiated avenue plantation of New Delhi stand tall.

MATERIAL AND METHODS

Study Area

With a total geographical area of 1483 km^2 Delhi has a continental climate due to its distance from the coast and location with respect to mountain ranges. The Yamuna River and terminal part of the Aravali hill range are the two main geographical features of the city. The Aravali hill range is covered with forests and is called the Ridges, and they are the city's lungs and help maintain its environment (Krishen 2006). The Yamuna River is Delhi's source of drinking water and is considered sacred for most of the inhabitants. At present the per capita green space availability in the city is 21.5 m^2 per inhabitant (Chaudhry et al. 2011).

Forest type mapping using satellite data, with reference to Champion and Seth classification (1968) reveals that Delhi has a single forest type, which belongs to the tropical thorn forest group. Delhi is divided into nine districts and the two districts selected for the study were New Delhi and South West Delhi (Fig. 1). With a geographi-

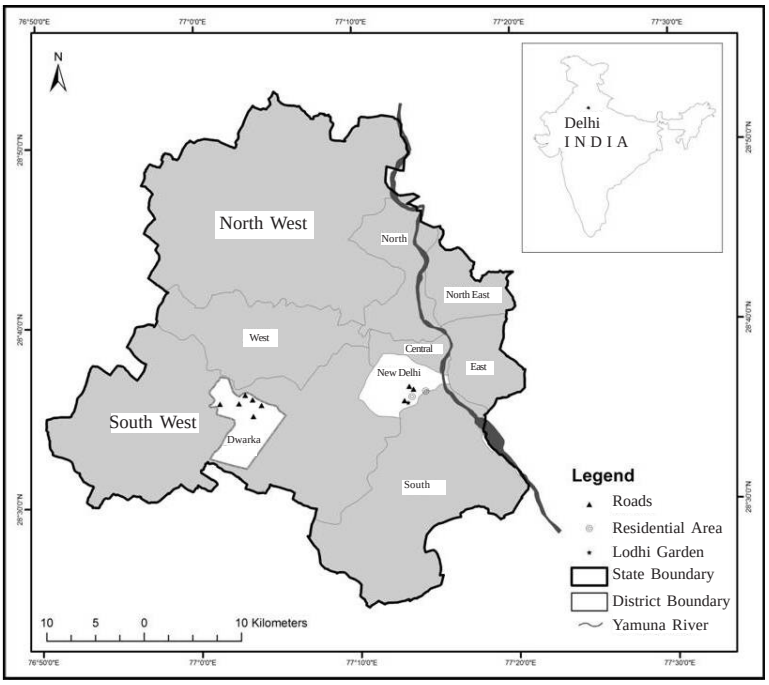

Fig. 1. Location of sample points within Lutyens' Delhi and Dwarka of NCT of Delhi
Source: Author

cal area of 35 km^2, New Delhi has 1.67 km^2 of very dense forest, 5.53 km^2 of moderate forest and 9.11 km^2 of open forests. Whereas, South West Delhi with a geographical area of 421 km^2 constitutes 2.37 km^2 of very dense forest, 12.70 km^2 of moderate forest and 26.73 km^2 of open forests (FSI 2011). Lutyens' Delhi zone located in New Delhi is maintained by New Delhi Municipal Council (NDMC). In contrast, the Dwarka zone, located in the South West Delhi is about a decade old and is maintained by DDA.

Dwarka is further divided into twenty-nine sectors out of which six sectors were randomly selected for the study purpose. These sectors were 4, 5, 6, 10, 12 and 16. Along with the 1 km road transects in each of these sectors, the residential societies and DDA parks situated beside these roads were also considered for conducting the survey to understand urban trees attributes and the people's perception regarding urban green space. The roads in New Delhi district named before the Mughal rulers of ancient India were randomly selected namely Shahjahan road, Prithviraj road and Akbar road for carrying out the study in Lutyens' Delhi area using the map made available by NDMC. Lodhi Gardens and two residential areas namely Kaka Nagar and Rabindra Nagar were also randomly selected for tree enumeration and conducting the survey for people's perception regarding urban green space. All these areas fall within the famous "Lutyens' Zone" of city of Delhi that was designed and created by the British before India's Independence. The area now comes under the jurisdiction of NDMC. Kaka Nagar and Rabindra Nagar cover an area of 0.25 km^2 and 0.17 km^2, respectively (NDMC brochure n.d.) are the two government residential colonies that mainly consist of trees planted by NDMC. The trees planted and maintained by NDMC only were considered for enumeration purpose, so as to understand their perception of planning and management.

Sampling and Data Collection

Field studies of urban tree distribution and residential survey were conducted from February to August 2011. Data was collected with the assistance of gardeners made available by the DDA and NDMC authorities. A random sampling method was employed to carry out the study. The maps for two areas were received from the respective authorities for locating the sampling points. Roads with similar width of 30m each were randomly selected within the two study areas and a sample transect of 1 km was identified within each sample road on which the study was conducted. Responses for residential perspective on urban forestry were collected using the Likert scale format and both, open and close-ended questions. A total of 60 respondents, 30 each in Lutyens' Delhi and Dwarka, were surveyed. Key informant interviews were conducted with the two responsible horticulture officials of NDMC and DDA, respectively to determine their role, personal views and perceptions on the manner how avenue trees are maintained, selected and accommodated in the urban landscape, and what challenges they face in establishment and maintenance. The information collected from interviews from the municipal officials was summarized and interpreted.

Data Analysis

Tree Enumeration

Primary data collected through field survey was subjected to simple descriptive statistics for analysis and the results were displayed through tables. The ratio data collected was analyzed for seven quantifiable parameters for both the study areas. The measured parameters were diameter at breast height (DBH), species composition and species density, species richness, relative abundance (RA), relative dominance (RD), species importance (SI) and size class distribution. All trees were identified to species level and the number of trees provided an indication of density. The DBH was determined for all trees planted on 1km road transects (right, left and central median), in Lodhi Gardens, in DDA parks and the trees planted by NDMC in residential societies of Kaka Nagar and Rabindra Nagar.

For the five most dominant species in each area, RA, RD and SI were determined, following McPherson and Rowntree (1989), and Welch (1994). Size class distributions were evaluated, using size as a proxy for age to determine whether changes in planting practices have taken place over time.

Residential Survey

The researchers also assessed the level of awareness of people based on certain principles of urban forests as developed by Clark et al. (1997). According to these principles, sustainable urban forestry possesses the characteris-

tics as follows, urban forest primarily provides service rather than goods, urban forest requires human intervention, and trees growing on private land compose the majority of urban forests. To accomplish this, the researchers drafted a formal survey questionnaire with questions relating to the individuals' perception towards trees. It included a Likert scale format and both open and close-ended questions. These questions addressed opinions about aesthetics, management, people's participation, willingness to pay and awareness of rules, laws and policies under governance.

Percentage response of respondents was measured to quantify the responses. The statements used for assessing the desired information were designed by self, based on literature review. Here, each respondent was provided with a set of six statements and for each statement under consideration three corresponding values were assigned in proportion to its relative importance, with a response of 1 indicating disagreement, 2 indicating neutrality and 3 indicating agreement with the respective statement. The respondent was asked to tick any one of the values for each statement. Since all the six statements may not be of equal importance for each individual surveyed, the weighted mean (x_w) was computed to consider relative importance of each statement, and is defined as,

$$\overline{x_w} = \frac{\sum_{i=1}^{n}(w_i . x_i)}{\sum_{i=1}^{n}(w_i)}$$

Where, w_e is the allocated weighted value (that is, 1, 2 and 3) and $\overline{\chi}_i$ represents the observed values.

RESULTS

A total of 1740 street trees were encountered in nine transects, with 491 in Lutyens' Delhi and 1249 in Dwarka. Table 1 represents that Lodhi Gardens alone sustain a population of 4380 trees, whereas a total of 451 trees were encountered in all the DDA parks of the sampled Dwarka area. The sampled residential colonies of Lutyens' Delhi consisted of 360 trees planted by NDMC but more of potted plants and shrubs were observed in the residential colonies of Dwarka, rather than trees planted by DDA.

The population of urban trees encountered in Lutyens' Delhi appeared quite diverse, with 125 species encountered in all the sampling locations as compared to 26 species in Dwarka. The two most commonly found species *shisham* (*Dalbergia sissoo*) and *jamun* (*Sygizium cumini*) together constitute about three-fourth of the total population of the sampled street trees in Dwarka. The most dominant species is the *shisham* tree, which constitutes thirty-nine per-

Table 1: Dominant species in gardens, parks and residential areas – number and percentage - summarized for two study areas, based on sample survey of the tree population

Location	*Sample area in acres (1 acre = 0.004047 Km²)*	*Total number of tree species*	*Number of trees*	*Dominant species*			
				Species Name			
				Scientific name	*Common names in India*	*Number of trees*	*Species percentage*
Lodhi Gardens	95	120	4380	*Callistemon viminalis*	Botllebrush	433	9.8
Kaka Nagar	Trees planted by NDMC	40	285	*Polyalthia longifolia*	Ashok	84	29.5
Rabindra Nagar	Trees planted by NDMC	20	75	*Cassia siamea*	Kassod	11	14.7
Sector 4 DDA park	2	9	184	*Callistemon viminalis*	Botllebrush	78	42.4
Sector 5 DDA park	13.96	6	58	*Morus alba*	Shahtoot	32	55.2
Sector 6 DDA park	1.75	15	184	*Dalbergia sissoo*	Shisham	50	27.2
Sector 12 DDA park	0.25	6	25	*Pongamia pinnata*	Karanj/papdi	14	56

Source: Author

cent of the total population studied. The two commonly found species in Lutyens' Delhi sampled road transects include *neem* (*Azadirachta indica*) and *imli* (*Tamarindus indica*) and constitute about half of the total population, with most dominant species as *neem* constituting twenty-five percent of the total population. Three tier plantation models, which cover the tall trees, shrubs/small trees and the hedges are planted here to address multiple returns like seeds, fruits, flower and ground cover. The average spacing encountered between street trees was 10m in both the study areas. The widest tree encountered throughout the survey was *peepal* (*Ficus religiosa*) and *pilkhan* (*Ficus virens*) with same DBH of 160 cm each, in Lodhi Gardens.

Table 2 summarizes differences in tree distribution and diversity across roads of two study areas. The number of trees within 1 km transect was greatest for Dwarka's sector 16 road (253 trees). Avenue trees in Lutyens' Delhi (average tree DBH, 47.9 cm) and Dwarka (average DBH, 19.1 cm) differ significantly in tree girth. Heterogeneity in tree girths was greatest in Lutyens' Delhi sample transects (standard deviation of 79.2 cm) while Dwarka sample transects had a more homogeneous distribution of tree girths (standard deviation of 33.5 cm). The proportional distribution of sampled trees DBH is given in Table 3. Roads in both the study areas had an average of 14 species per transect, with the maximum diversity of 24 species per transect in Shahjahan road of Lutyens' Delhi followed by 22 species per transect in Dwarka's sector 12 road. A minimum of nine species per transect was observed in Prithviraj road of Lutyens' Delhi.

Table 4 lists the five most dominant avenue tree species found in both the sampled study areas of NCT of Delhi. While three of the dominant species are common to both the areas, there are some differences. *Pilkhan* (*Ficus virens)* a broad canopied tall tree is absent from the list of dominant species for Lutyens' Delhi. *Jamun* (*Syzigium cumini*) and *imli* (*Tamarindus indica)* are the most dominant fruit bearing trees in their respective study areas with a difference in their ripening and setting time. *Jamun* ripens in late June or July whereas *imli* ripens in winter (Krishen 2006). No mango (*Mangifera indica*) tree was encountered in Dwarka (Table 5). *Amaltas* (*Cassia fistula*) though found moderately planted in Lutyens' Delhi sampled transects is hardly observed in Dwarka. *Amaltas* with its bright yellow flowers provides the much needed shade along with aesthetic pleasure. *Peepal* (*Ficus religiosa*) is considered sacred and is commonly used for worship in Delhi. *Neem* (*Azadirachta indica*) is a medicinally important tree and *shisham* having a medium canopy size offer its use as timber and is heavily planted in Dwarka sectors.

While different species grow at different rates, the size class distributions of these species can provide a fairly reliable overall indication of changes in species selection over time (Sanders 1983; Welch 1994). Thus, one should be able to use size class distributions to differentiate between species which have been planted over a number of years (which should have a more evenly distributed age structure), from species which have been selected for planting recently (whose distribution should be dominated by smaller trees), or species which have been

Table 3: Proportional distribution of tree DBH across sampled streets in two study areas of NCT of Delhi

DBH (cm) range	*Proportional distribution*	
	Dwarka	*Lutyens' Delhi*
0 - 25	0.64	0.28
25 - 50	0.35	0.24
50 - 75	0.01	0.26
75 - 100	0.00	0.19
> 100	0.00	0.02

Source: Author

Table 2: Attributes of avenue trees – density, size and diversity – summarized for two study areas, based on sample survey of the avenue tree population

Avenue tree attributes	*Dwarka*	*Lutyens' Delhi*
Tree density (per Km) - mean and standard deviation	208.2 ± 34.2	163.7 ± 6.7
Range of tree density (per Km) - minimum and maximum	156-253	156-168
Average DBH (cm) - mean and standard deviation	19.1 ± 33.5	47.9 ± 79.2
Range of DBH (cm) - minimum and maximum	0-68.5	0-124.2
Species richness - mean standard deviation	14.3 ± 4.5	14.3 ± 8.4

Source: Author

Table 4: Five most frequently encountered avenue tree species and their relative abundance (percentage of the total number of trees constituted by the species), relative dominance (percentage of total basal area constituted by the species), and species importance (sum of relative abundance and relative dominance), based on a sample survey of the avenue tree population in both the study areas of NCT of Delhi

Study area	*Abundance rank*	*Species name*	*Relative abundance*	*Relative dominance*	*Species importance*
Dwarka	1	*Dalbergia sissoo*	0.39	0.41	0.80
	2	*Syzigium cumini*	0.34	0.40	0.74
	3	*Ficus virens*	0.04	0.05	0.09
	4	*Azadirachta indica*	0.03	0.01	0.04
	5	*Ficus religiosa*	0.02	0.05	0.07
Lutyens' Delhi	1	*Azadirachta indica*	0.25	0.41	0.66
	2	*Tamarindus indica*	0.18	0.26	0.44
	3	*Ficus religiosa*	0.18	0.18	0.36
	4	*Cassia fistula*	0.10	0.02	0.12
	5	*Dalbergia sissoo*	0.04	0.01	0.05

Source: Author

Table 5: Fruit tree species as avenue trees – proportion of all fruit species in two study areas of NCT of Delhi

Tree species	*Proportion of species*	
	Dwarka	*Lutyens' Delhi*
Syzigium cumini	0.91	0.06
Mangifera indica	0.00	0.08
Morus alba	0.03	0.14
Agle marmelos	0.06	0.00
Tamarindus indica	0.01	0.73

Source: Author

planted widely in the past and recently been discontinued (whose distribution should therefore be dominated by larger trees). Table 6 clearly indicates differences between species age structures. In Dwarka, *shisham* is dominated by individuals in the smallest size category of 0-25 cm DBH, but has no individuals in the largest size class of >100 cm, DBH. In fact, no tree was encountered in Dwarka sampled transects to have a DBH of 100 cm or more, DBH. In Lutyens' Delhi *neem, imli* and *peepal* are dominated by large sized individuals, but not to the same degree. Of these three species *neem* and *imli* have a relative dominance that is greater than their relative abundance (Table 4), indicating that these species are dominated by large sized trees that are older relative to the rest of the population (McPherson and Rowntree 1989). Visually *neem* dominates the streetscape of Prithviraj road and *imli* dominates the Akbar road. It is clear from the distribution that avenue trees in Lutyens' Delhi appear to have a healthy age distribution, with older and younger trees. Dwarka, on

Table 6: Size class distribution of five most dominant species in Dwarka and Lutyens' Delhi, based on sample survey of the street tree population in NCT of Delhi

Study area	*Species*	*Species percentage of DBH class (cm)*					*Number of trees*
		0 - 25	*25 - 50*	*50 - 75*	*75 - 100*	*>100*	
Dwarka	*Dalbergia sissoo*	60.1	38.9	1.0	-	-	489
	Syzigium cumini	69.9	30.1	-	-	-	428
	Ficus virens	58.3	37.5	2.1	2.1	-	48
	Azadirachta indica	81.8	18.2	-	-	-	44
	Ficus religiosa	55.2	41.4	3.5	-	-	29
Lutyens' Delhi	*Azadirachta indica*	12.2	4.9	38.2	42.3	2.4	123
	Tamarindus indica	9.2	8.1	50.6	32.2	-	87
	Ficus religiosa	25.3	32.2	20.7	14.9	6.9	87
	Cassia fistula	58.8	39.2	1.9	-	-	51
	Dalbergia sissoo	57.1	38.1	4.8	-	-	21

(- no tree was identified)
Source: Author

the other hand, consists of more individuals of younger trees with a nearly uniform distribution of *peepal* and *pilkhan* trees. Thus, from the analysis it can also be said that the proportion of old, mature street trees in Lutyens' Delhi appears to be decreasing over time with increase in the percentage of younger to medium sized trees.

Residents' Perceptions of Urban Green Spaces

The residents were interviewed in their respective colonies. The socioeconomic profile of respondents surveyed in Dwarka area was sixty-six percent females and thirty-four percent males. In Lutyens' Delhi it was sixty percent females and forty percent males. Respondents above the age of 15 years were interviewed and categorized into four age classes that is 15-30, 30-45, 45-60 and above 60.

Cooling (from shade) and the aesthetic value of trees were the two benefits most commonly cited in the conversations with the residents from both the study areas. More than fifty percent of the respondents from both the study areas utilized the shade for sitting purposes besides parking and playing. Despite few similarities, opinions varied with respect to the study area. Forty three percent of the respondents in Dwarka cited a decrease in the associated faunal biodiversity over the years (Table 7). Whereas, seventy-six percent of the respondents from

Table 7: People's perception regarding urban green spaces – response percentage for residential survey conducted in both the study areas of NCT of Delhi

S.No.	*Survey question*	*Options given*	*Response %*	
			Dwarka Area	*Lutyens' Delhi*
1	Perception of benefits	Flower	26.6	33.3
		Shade	10.0	20.0
		Beauty	6.7	6.7
		Fragrance	10.0	6.7
		All	46.7	33.3
2	Choice of plant	Shrubs	26.7	30.0
		Trees	26.7	33.3
		Climbers	40.0	20.0
		All	6.7	16.7
3	Faunal biodiversity changes observed	Increasing	33.3	50.0
		Decreasing	43.3	33.3
		Neutral	23.3	16.7
4	Is the shade from tree canopies enough	Yes	46.7	60.0
		No	53.3	40.0
5	Knowledge of surrounding trees	All	46.7	40.0
		None	33.3	16.7
		Few	20.0	43.3
6	Faunal biodiversity	Butterflies	20.0	23.3
		Birds	33.3	30.0
		Insects	13.3	13.3
		Squirrels	20.0	26.7
		Peacocks	13.3	6.7
7	Shade utilized for	Playing	13.3	20.0
		Sitting	50.0	53.4
		Parking	16.7	13.3
		All	20.0	13.3
8	Is the area well managed and organized	Yes	30.0	66.7
		No	53.3	30.0
		Neutral	16.7	3.3
9	If interference of electricity wires/cables observed	Yes	36.7	30.0
		No	63.3	70.0
10	Frequent meetings set-up	Yes	30.0	76.7
		No	70.0	23.3
11	Plan and observe activities	Yes	10.0	16.7
		No	90.0	83.3
12	Willingness to pay for service and maintenance	Yes	80.0	86.7
		No	10.0	0.0
		Neutral	10.0	13.3

Source: Author

Lutyens' Delhi appreciated the fact that frequent meetings are set up by the resident welfare association (RWA) in their colonies, which is a rare case observed in Dwarka sectors. More than eighty percent of the respondents from both the areas expressed their concern regarding lack of efforts made for planning plantation programs in their respective areas. Majority of the respondents from both the areas were willing to pay for the maintenance and care for the urban trees planted in their area though a few residents were not excited about the prospect of more trees in the neighborhood. The respondents in Lutyens' Delhi showed their willingness by planting seeds anytime in the year (preferably in monsoon), but no plantation week was celebrated. Residents of Dwarka societies highlighted abundance of only *jamun* trees and the absence of mixed variety of fruit trees in and around their societies, whereas the residential colonies of Rabindra Nagar and Kaka Nagar in Lutyens' Delhi have a mixed variety of fruit trees, which includes *Mangifera. indica*, *Psidium guajava* and few *Musa paradisiacal* trees. A single birdhouse was found at the Lutyens' Delhi Rabindra Nagar residence colony. None of the respondents were aware about the guidelines of urban green areas and landscaping made by the Ministry of Urban Development and Poverty Alleviation, one of which states that an area of 1.8X1.8 m^2 should be left "uncemented" around each tree to ensure it gets enough breathing space. The knowledge and understanding about the sacred trees present in their residential colony or society was high. Majority of the responses indicated *Ficus religiosa, Ficus benghalensis*, *M. indica* and *Agle marmelos* trees and *Ocimum sanctum (tulsi)* plant that they had kept in their premises, for worship purpose. The respondents also mentioned about the name of the flowers they used from local gardens for offerings while worshipping any religious place. The flower names include *Hibiscus* species, *Calendula officinalis*, *Plumeria rubra* and *Tabernaemontana divaricata*.

The relative importance of each statement indicating the level of agreement was determined in response to all the 60 respondents. The weighted mean analysis in Table 8 indicates that all the respondents were in agreement with the first five statements. Whereas, they showed a neutral behaviour towards the last statement that mentioned about the necessity to get involved in urban forestry related activities.

Management and Planning

The various agencies involved in the Delhi greening program face a number of challenges besides administrative bottlenecks in maintenance. In order to accommodate the population pressure, the colonies of Delhi are becoming very congested. As a result, the open space left for the greening aspect is shrinking at a faster rate. On the other hand, improper usage of urban parks and gardens for daily activities like drying clothes and car parking is observed commonly.

Despite many similarities in maintaining the urban forests in their respective areas, differences arise as a result of different land use structures and species diversity. General management practices like, pruning operation, replacement, manure application, transplantation, disease recovery mechanism, seed and leaf litter collection, canopy trimming, watering and other spe-

Table 8: Relative importance of statements by all residents, based on residential survey conducted in both the study areas of NCT of Delhi

Statements	*Response (%)*			
	Disagree	*Neutral*	*Agree*	*Weighted mean*
Trees in urban areas are beneficial to human health.	3.3	10.0	86.7	2.8
Trees in urban areas increase its beauty.	5.0	6.7	88.3	2.8
Trees in urban areas reduce air pollution and assist in odor control	11.7	18.3	70.0	2.5
There is an urgent need to launch efficient urban forestry program in your city	10.0	30.0	60.0	2.5
Roadside plantations are necessary in the city	6.7	20.0	73.3	2.7
People's involvement in urban forestry activities is necessary	18.3	41.7	40.0	2.2

Source: Author

Table 9: Management matrix for urban plantations in Lutyens' Delhi and Dwarka

S. No.	*Parameter*	*Month*	*Mode of operation*	*Frequency*	*Who does*
1	*Lopping/Pruning operation*	Dec-Feb / Jun-Aug	Hedge cutter, tree pruner	Annually - biannually	Gardener
2	*Replacement*	Monsoon season	Manually	As required	Gardener
3	*Manure Application*	Dec-Feb / Aug-Sep	Spreading, spraying and digging	Twice or thrice in a year	Gardener
4	*Watering*	All months	Sprinkler, hydrant system, water tanks	Weekly in summers and fortnightly in winters	Gardener
5	*Transplantation*	Monsoon season	Using crane	During road/ building construction	Gardener
6	*Disease Recovery*	As required	Foliage application, spraying, pasting and surgery	As required	Plant protection cell staff
7	*Spray of Pesticides/ Chemicals*	As required	Manually wearing gloves	As required	Gardener
8	*Special Efforts for Bird Nesting*	Naturally on flowering and fruiting tree species			
9	*Seed Collection/ Leaf Litter Collection*	May - June	Manually using garden rack, hooked stick and seed box	Round the year depending on maturity of tree	Specialized senior staff
10	*Canopy Trimming and Modification*	During winters and Monsoon	lawn mower, hedge shear and manually by lopping	As required	Plant protection cell staff

Source: Author

cial efforts were addressed against the month, frequency, mode of operation and the kind of performer. Various garden tools and tree cutting techniques that are used by gardeners (also called as *'mali'*) are provided in Table 9. Key features noticed were as follows. No special effort for bird nesting was performed in both the areas by planting more flowering species, though a hierarchy of gardeners is appointed in both the areas, the frequency of training and seminars is observed to be inadequate. As a result, only few senior gardeners feel confident in their knowledge and work. Much attention is paid to parks and gardens keeping street trees as secondary. Many street trees in Dwarka had no breathing space left due to concretization. The same issue has been raised in several forums and recently authorities have started addressing it for the roadside plantation

The problem of continuous demands of pruning of trees is also growing, as people prefer low height trees and rounded bushes. A gardener who is considered as the important resource for maintenance of park is provided for 1.5 acre of park area and is assigned 5 to 15 parks on an average. Such divided resources make it more difficult to maintain and manage plus the supervision also gets diffused. Water, which is the most important resource for maintenance, is another problem for the parks. In the parks, water is provided through tube wells and efforts have been made to have at least one tube well in the park and to interconnect the parks by pipes. On a positive side, the Public Private Partnership (PPP) scheme envisages development of parks by involving RWA and NGO's. The model of joint park management under this scheme of MCD has proved to be a useful tool in development and maintenance of parks in Delhi. Every year Delhi government provides huge financial allocations for the maintenance and protection of urban green trees to maintain the city's biodiversity as compared to the natural forests. Whereas, the tree diversity in natural forests of Nagpur as per Chaturvedi et al. (2013) is protect-

ed more than the plantations undertaken by civic authorities and private sector.

DISCUSSION

Presently, the town planning authorities are taking the easy way out by planting fast growing species in large numbers, rather than selecting species after appropriate sustainability studies. Also, with urban environment stresses like poor drainage, bad soil conditions, frequent pruning and proximity to traffic pollution, tremendous survival challenges for the newly planted trees exists. Soil quality, space limitation, and concretization, water and nutrient availability that are stressors to tree growth, make trees susceptible to pest attacks. Studies by McPherson and Rowntree (1989), Galvin (1999) and Thaiutsa et al. (2008) further suggest that the presence of high species diversity provides protection against such challenges and therefore supports the fact that species diverse Lutyens' Delhi may be more protected than Dwarka region. Further, Muthulingam and Thangavel (2012) in support consider tree inventory by city authorities important in managing the trees more systematically.

Overall, *D. sissoo* being the most dominant species in Dwarka comprises thirty-nine percent of the total street trees sampled as compared to *A. indica* in Lutyens' Delhi, which constitutes twenty-five percent of the total population of sampled street trees. In contrast to this the five most common species in Hong Kong constitute over fifty percent of the total population (Jim 1987). The frequency of trees (164/km in Lutyens' Delhi and 208/Km in Dwarka) is more than in other Asian cities, notably in Bangkok and Bangalore, where the number of street trees is approximately 168/km (Thaiutsa et al. 2008) and 100/km, respectively. But Delhi still lacks uniform distribution of mixed tree species diversity and its associated biodiversity, though trees are being planted in huge numbers, especially in new developmental areas. While sharing approaches to enhance urban biodiversity, Savard et al. (2000) suggest that besides planting trees only one should also focus on creation, restoration and management of natural areas, regulating human behavior, setting provisions of bird feeders and creating artificial nesting sites in order to achieve ecosystems rich in biodiversity.

Results depict differences in the species girth distributions indicating the abundance of young urban trees in Dwarka in comparison to Lutyens' Delhi. Old and mature trees, like those in Lutyens' Delhi can assist in combating the urban heat island effect. Whereas, young trees, though planted in large numbers, find the task difficult. Uniform density of urban trees is seldom observed in the city. With very few mature and old trees, Dwarka streets are majorly dominated by *D. sissoo* trees, of which sixty percent trees lay in the smallest DBH class of 0-25 cm. The likely reasons for this dominance of *D. sissoo* are its quick establishment, easy availability of seedlings and resistance to frost and dry conditions. Saline soil and low ground water table level in Dwarka, as reported by the concerned management authorities are responsible for moderately successful plantation of other tree species. Similarly, considering trees like *S. cumini*, prefers clayey or sandy loam and once established survives in drought conditions. Young and mature *Cassia siamea, Polyalthia longifolia, Ficus religiosa and Ficus glomareta* were also planted along the sample transects in Dwarka as they are fast growing species and drought hardy. Further, in support Pandey et al. (2015) suggest *Ficus Benghalensis L., Ficus religiosa, Polyalthia longifolia, Ficus glomerata (Roxb), Mangifera indica, Cassia fistula L., Drypetes roxburghii, Terminalia Arjuna, Psidium guajava L* and *Dalbergia sissoo* as air pollution tolerant plants to be considered for urban forest development with particular reference to Varanasi, based on the air pollution tolerance index and anticipated performance index. *Neolamarckia cadamba*, a rapid growing pioneer species that has the capability to colonize fresh forest clearings or vacant ground was found to be three in number in Dwarka sampled transect as compared to 36 in Lodhi Gardens in Lutyens' Delhi. Appropriate choice of species requires field-testing and detailed knowledge of its habitat prior to establishment. *Delonix regia* and Bougainvillea species for example prefer a warm climate with a pronounced dry season, but has a shallow root system and the ground beneath it often becomes bare because its surface roots monopolize all nutrients and water (Krishen 2006). Therefore, careful planning before any tree plantation at a specific site is deemed necessary. A marked difference in the color of flower was observed in the dry areas where the red color appears faded, whereas with good groundwater,

dark red blooming was observed in *D. regia*. Tree species that can survive hard conditions were planted in both study areas. These included *Cassia fistula, Prosopis juliflora and Acacia nilotica* that tolerate poor, rocky and shallow soil, are superbly adapted to drought, heat and mild salinity. The Herbal Garden in Lodhi Gardens, with 30 such species provides an example by which medicinal plants can be cultivated in a very effective way to be used as home remedy for the common ailments.

Active involvement in tree planting programs has been shown to enhance a community's sense of social identity, self-esteem, and territoriality (Dwyer et al. 1992). Overall, survey participants indicated a strong interest in having greener surroundings. Although the sample size was small, the survey showed the potential of outreach initiatives to increase awareness of tree benefits. Bigger surveys, particularly by local planning authorities and circulation of educational brochures, would be useful. Avenue trees require frequent maintenance, which highlights the need for appropriate planning and management that becomes difficult when financial resources are limited.

Urban green space is used directly or indirectly by human beings. In Dwarka, scores of people had set up their shops beneath *Alstonia scholaris, Albizia lebbeck, F. religiosa, S. cumini, Pongamia pinnata, D. sissoo* and *A. Indica* as these trees provide dense shade. A large number of poor migrants in Delhi get their fuel wood for daily cooking from dry branches of big trees available on the roadside. There are different kinds of livelihood activities observed in the form of different professions like that of a cobbler, tea stall owner, barber, juice bar owner, bicycle repair shop owner and vegetable vendor.

CONCLUSION

The findings indicate the critical need to protect the remaining old population of street trees, with a focus on caring for large, mature individuals, planting more trees and selecting an appropriate and diverse mix of large and small sized tree species for such new planting. The case study of urban green space and their attribute data on street trees acts as a useful tool as it can be fed into the broader context of the biodiversity conservation to balance with urban growth and to create a livable habitat for common people. Focusing on the aspects of street tree density, size, diversity, and distribution, the researchers find that Dwarka streets are relatively low in species diversity but high in density, with maximum number of young trees as compared to Lutyens' Delhi. Such information is essential for effective management of trees in urban areas and highlights the need for strengthening coordination among concerned stakeholders working in the field of urban biodiversity and green spaces to identify specific characteristic features of urban tree species for reducing the effect of environmental pollution, or that can be used as bio-indicator species form further areas to be researched upon.

RECOMMENDATIONS

The urban biodiversity and green spaces concept should be integrated into a wide variety of urban development projects. Well-researched land use planning should be done to ensure sustainability of urban green spaces. With creation of small or big water bodies' support to urban birds and fauna can be established. Any new housing, business or public building landscape rating concept may be initiated wherever possible. It should be the goal that all residential housing societies have green spaces, and that they follow the guidelines prescribed by the Delhi government. Incentives could be developed to encourage this goal. Award for private or housing societies for best garden in society must be encouraged to promote urban forestry. PPP are often advocated as a tool for good governance and civil society organization requires working and focusing on the urban green development and maintenance aspect. Besides these, periodical tree inventories must be carried out and relevant data to policymakers.

Practice of roof top garden should be encouraged for development of green infrastructure. Quality certification must be initiated for best landscaping and quality gardens, as this would not only promote aesthetic value but also encourage peoples' participation. Involvement of people at all levels, for plantation activities and celebrating environment related dates must be encouraged in societies and colonies.Further, a combination of flowering and fruit species along with variety of shrubs and climbers must be planted in equal proportions, so as to enrich

ecological sustainability and biodiversity. Practicing excessive pruning and concretization should be avoided as it deteriorates the health of the tree. Incorporation of plantation activity in university programs and other courses and offices can add a lot to expand the urban green space in the city. Also, introduction of urban forestry as a chapter at the school level, as a course at college level and as an area of research needs to be promoted.

LIMITATIONS

The only limitation of the survey was the small sample size of residents, that is, only those who were available and interested took the survey.

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