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Impact of time scale on plantation pattern: an approach to access tree diversity changes in urban parks

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Urban parks are an important part of the city's green infrastructure and serve as an indicator for the city's natural environment. Six urban parks in Faisalabad were evaluated, split into two categories: Old parks (OP) and New parks (NP). A thorough census of tree populations was conducted in specified urban parks, and many parameters were studied. The composition of trees, species richness, and distribution of native and exotic trees were evaluated among two types of parks. Tree stem count was used to calculate the diversity benchmark (10/20/30) for tree inventories in selected urban parks. The major objective of the study was to determine the difference in species richness and diversity indices of selected urban parks in both categories. Evaluation of the plantation of Urban parks on the basis of the proposed benchmark (10/20/30) was also the key objective of the present study. The results revealed that 2978 trees from 52 species, 45 genera, and 22 families had been counted, with 2004 trees in the OP and 794 in the NP. A few common species hold the majority of the distribution. OP have higher share of native trees (67.07%) while NP have higher share of exotic trees (59.32%). The dominance of exotic tree species in NP depicted that change in time has significantly affected the plantation pattern of urban parks in Faisalabad. OP had higher tree species richness (47) as compared to NP (36). The dominance of exotic species in new parks is the major cause of low tree diversity. Results of the tested benchmark indicated that the plantation of selected urban parks approximately failed to achieve the proposed diversity benchmark. In urban parks, more attention should be paid to the plantation design and species selection. The pressing need of the hour is to have a tree mix that promotes biodiversity while also maximizing ecological services.
Keywords: Species richness, basal area, park management, urban trees, diversity indices.

INTRODUCTION

The current epoch, known as the Anthropocene, is characterized by human influence, and it has brought with it a growing number of direct and indirect threats to people's health and prosperity, as well as the planet's (Ellis, 2015). The urbanization rate in emerging countries is on the rise, resulting in an increased societal burden in metropolitan areas, because of their limited capacity to adjust to the socioeconomic constraints of new settings (Laros and Jones, 2014). According to global forecasts, urbanization tendencies might quadruple between 2000 and 2030 (UN, 2014; Angel *et al.*, 2011; Rajkumar and Parthasarathy 2008; Seto *et al.*, 2012; Agbelade *et al.*, 2017). The rapid growth of the human population has caused an environmental imbalance in both urban and rural places. It is estimated that half of the world's population now lives in less than 3% of the world's urbanized surface. These densely populated areas have numerous obstacles, ranging from a lack of clean water to pollution-related health problems (UN, 2015). As the worldwide population of urban dwellers grows and challenges connected to sustainable development in an urban context become more important, many questions remain unanswered, particularly how to effectively use urban green infrastructure to progressively improve the quality of the urban environment.

Parks, public green space, street trees, allotments, green corridors, urban forests, roof and vertical greening, private domestic gardens, and cemeteries are examples of urban green infrastructures (Zhang and Jim, 2014; Kowarik *et al.*, 2016). Research has indicated that many types of urban green infrastructures not only help to improve the urban ecology, but also increase the quality of life for the city people (Stoffberg *et al.*, 2010; Escobedo *et al.*, 2011), but also increase the quality of life for city (*Cohen et al.*, 2007; Shanahan et al., 2015). Urban parks are municipally owned and operated public spaces in urban regions and other incorporated locations that provide leisure and green space to inhabitants and tourists (Evert, 2010). Urban parks participate

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in a variety of ecological functions like as the natural forest (Jankovska *et al.*, 2013), for example improvement of the urban heat island effect (Lee *et al.*, 2009), regulation of microclimate (Andrade and Vieira, 2007), prevention of soil and water loss (Chiesura, 2004; Sjöman *et al.*, 2012; Kirnbauer *et al.*, 2013), purification of air and water, filtration of wind and noise (Yang *et al.*, 2015; Cohen *et al.*, 2014) and carbon fixation (Bjorkman *et al.*, 2015). In addition, urban parks are important for biodiversity preservation (Schmitt and Goetz, 2010; Stagoll *et al.*, 2012; Aida *et al.*, 2016) and mitigation of global biodiversity loss (Alvey, 2006; Celesti-Grapow *et al.*, 2013), especially when parks have regions that are more or less similar to natural ecosystems (Cornelis and Hermy, 2004). Although many urban parks are not very big, they may make a high contribution to the biodiversity of a city (Nielsen *et al.*, 2014).

Some of the most species-rich urban green zones are found in urban parks (Savard *et al.*, 2000; Cornelis and Hermy, 2004; Nielsen *et al.*, 2014). Despite their modest size, they are associated with high levels of variety and microhabitat heterogeneity, as well as a high number of exotic species (Khera *et al.*, 2009), as well as being crucial hotspots of biodiversity (Cornelis and Hermy, 2004; Goddard *et al.*, 2010). There is much debate about whether the advantages of non-native species exceed their negative aspects. Many non-native plants may improve urban biodiversity and provide a variety of aesthetic and financial advantages to humans (Gaertner *et al.*, 2017; Zengeya *et al.*, 2017). Exotic species have unfavourable characteristics such as increasing the severity or frequency of fires and floods (Pejchar and Mooney, 2009), or destroying natural fauna's habitat. Furthermore, even in ecologically diverse urban environments, when native species are replaced by non-native species, critical functions of vegetation might be lost. Therefore, there is a need for the collection of data on tree census and several other elements for sustainable development and management of tree plantation (Maco and McPherson, 2003).

Despite their significance, urban green places are understudied in most regions of the world (Davies *et al.*, 2008; Clarke *et al.*, 2008), in contrast to the focus on trees in wooded regions (Nagendra, 2008). Due to a scarcity of knowledge on the distributions and dynamics of tree diversity in urban parks, developing strategies for tree diversity conservation is quite challenging (Weifeng *et al.*, 2006; Jim and Chen, 2009). The majority of research on urban parks, has taken place in different countries of North America and Europe, with only limited studies from other regions of the globe (Fernández-Juricic and Jokimäki, 2001). Australia, Southeast Asia, and Russia have been the focus of the few research undertaken in Asia/Pacific (Jim and Liu, 2001; McKinney, 2008), very limited knowledge of urban forests, particularly urban parks are available in South Asia (Nagendra and Gopal, 2010; Singh *et al.*, 2010).

In Faisalabad, urban parks before 2010 were managed by Muncipal Coorporation Faisalabad and after 2010 they were managed by the Parks and Horticulture Authority. This article analyses how Faisalabad's urban parks' tree species diversity and composition have changed over time and how the plantation of selected urban parks scores on the selected diversity benchmark and three diversity indices. It is that hypothesized relative abundance of tree species will be higher than diversity benchmarks at the species, genus, and family level. It’s also hypothesized that exotic plant species will be more dominant than native plant species in the selected urban parks of Faisalabad. With the help of this study, we can better understand the shifts in people's preferences for planting trees in urban parks and draw conclusions about how urban parks in crowded cities can be planned and operated to promote biodiversity and more environmentally sustainable management.

MATERIALS AND METHODS

This study focuses on a few of Faisalabad City's most noteworthy urban parks. Six main urban parks (Jinnah Bagh: 1°25'04"N 73°05'20"E, D Ground Park: 31°24'29"N 73°06'34"E, Kaleem Shaheed Park: 31°26'04"N 73°02'05"E, Lyallpur Park: 31°26'25"N 73°04'06"E, Shahbaz Shareef Park:31°26'29"N 73°03'28"E, Dhobi Ghat Park:31°25'04"N 73°04'20"E) selected for this purpose were represented in (Fig. 1), totaling 47.64 ha area. A direct tree census performed in the survey region in 2021 served as the foundation for the investigation. Trees with DBHs of more than 10 cm were evaluated.

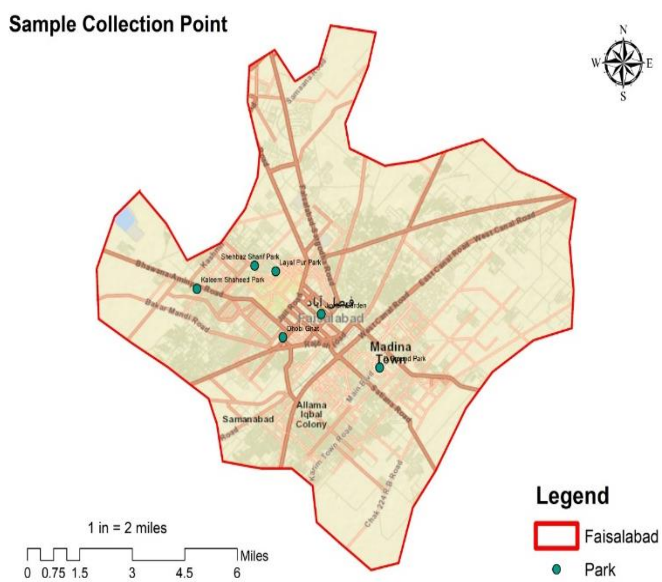

Figure 1. Map of selected urban parks (Lyallpur Park, Shahbaz Sharif Park, Dhobi Ghat Park, Kaleem Shaheed Park, Jinnah Bagh) of Faisalabad

Computation of Growth Parameters**:** The following growth parameters have been computed.

Basal Area**:** By using the following equation, the basal area of all trees was determined (Agbelade *et al.,* 2017).

$$\text{BA} = \frac{\pi D^2}{4}$$

Where: BA stands for basal area (m^2), ***D*** represents diameter at breast height (m), and π valued as (3.142).

Species Relative Density (RD)**:** It is an indicator used for analyzing the relative distribution of species (Brashears *et al.*, 2004). Species Relative Density was calculated using the following equation:

$$\text{RD} = \frac{n_i}{N} \times 100$$

where RD (%) represents species relative density, n_i counts the individuals of species I, and N represents the count of total individual trees of all tree species in selected urban parks.

Species Relative Dominance (RDo)**:** Species Relative Dominance (RDo), which is used to measure a tree's relative space occupancy, was calculated using (Aidar *et al.,* 2001).

$$\text{R}D_O = \frac{(\sum Ba_i \times 100)}{\sum Ba_n}$$

where Ba*i* represents the total basal area of all trees of a specific species *I,* and Ba_n represents the total basal area of all trees in selected urban parks.

Importance Value Index (IVI)**:** The Importance Value Index (IVI) of each species was calculated using the equation below. (Brashears *et al.*, 2004)

$$\text{IVI} = \frac{(RD + RD_O)}{2}$$

Species diversity indices and statistical computation**:** A diversity index, in terms of numerical value, indicates the structure of a biological community. It typically provides more information regarding community diversity than merely species abundance. Furthermore, the diversity index can provide information about the commonness and rarity of species in an ecosystem, making it a significant tool for scientists in their understanding of ecosystems.

Simpson (Simpson, 1949), Shannon Evenness, and Shannon–Wiener index ((Kent and Coker, 1992), were selected as species diversity indicators. The Simpson index determines the probability that a second individual chosen from a population (vegetation community) will be of the same species as the first. The Shannon Evenness (H_E) refers to the pattern of individual distribution among species. The Shannon-Wiener index measures a vegetative community's species heterogeneity.

Statistical Analysis**:** All the gathered data was entered into a Microsoft Excel database for statistical analysis. Results were interpreted according to obtained values.

RESULTS

Tree Species Composition**:** The results of the current investigation revealed the presence of 2798 trees in six urban parks, representing 52 species, 45 genera, and 22 families. *Terminalia ivorensis* (377), *Conocarpus erectus* (374), *Alstonia scholaris* (213) and *Ficus virens* (189) were the most abundant species in terms of numbers (Table 1). According to our results, relative density (RD) of individual trees in urban parks ranged from 0.03 to 13.47 percent (Table 1). High relative density (RD) tree species were *Terminalia ivorensis, Conocarpus erectus*, *Alstonia scholaris*, and *Ficus virens*, accounting for (13.47%), (13.36%), (7.61%) and (6.75%) respectively. Relative Dominance (RDo) of tree species varied from 0.00004 to 17.47% (Table 1). High relative dominance (RDo) tree species were *Terminalia ivorensis, Alstonia scholaris, Ficus virens* and *Conocarpus erectus* accounting for (17.47%), (17.21%), (16.20%), and (10.42) respectively. In selected urban parks tree species with the maximum Importance Value Index were *Terminalia ivorensis,* (15.47), *Alstonia scholaris (12.41), Conocarpus erectus* (11.89), followed by *Ficus virens* (11.47), and *Roystonea regia* (5.59%) (Table 1). Of the 52 species encountered 36 were native and only 16 were exotic species. According to abundance, native tree species made up 59.52% of the total number of trees, while exotic tree species make up 40.42%. A small number of frequently occurring species predominate throughout the distribution. Nearly 13.47% of the whole population is made up by the most prevalent tree, *Terminalia ivorensis*, an exotic evergreen tree species imported from the African subcontinent. The top six most prevalent species made up approximately half of the total population. Out of a total of 22 families to which all the tree species of public parks belong, Fabaceae ranks first and contribute 16.47 % of total tree population with 9 tree species, followed by Moraceae making 15.54% of total tree population with 9 tree species, followed by Areaceae(4), Malvaceae(4), Bignoniacae (3), Combretaceae (3), Myrtaceae (3), Apocynaceae (2), Meliaceae (2), and Anacardiaceae, Boraginaceae, Ebenaceae, Lythraceae, Mimosceae, Oleaceae, Papilionaceae, Putranjivacae, Pinaceae, Proteaceae, Rhamnaceae, Sapotaceae and Ulmaceae each with one species (Table 3). Lyallpur Park and Shahbaz Sharif Park (22) had the lowest species richness among all of the urban parks, whereas Jinnah Bagh (41) had the highest species richness. Maximum tree count was recorded at Kaleem Shaheed Park (893) while minimum tree count was recorded at Dhobi ghat Park (207) (Table 5). Urban parks established before 2010 have greater species richness (47) while urban parks established after 2010 have lower species richness (36). Maximum tree (2004) was recorded in urban parks established before 2010, while parks established after 2010 have lower tree count (794) (Table 2).

Native vs Exotic tree Species**:** In selected urban parks, there are 36 native tree species and 16 exotic species. Native tree species account for 60.04% of total tree count, whereas exotic tree species account for 39.96%. Bagh-e-Jinnah has the most species richness of native trees (31), whereas Shahbaz Sharif

Table 1. Tree inventory on the basis of origin (native, exotic), Basal area, Species relative density, Species relative dominance and Important value index of selected urban parks in Faisalabad.

Sr.	Botanical Name	Family	Origin	Tree count	*BA (m)	*SRD	*SRDo	*IVI
1	*Terminalia ivorensis*	Combretaceae	Exotic	377	3947.12	17.470	13.47	15.47
2	*Conocarpus erectus*	Combretaceae	Exotic	374	2355.65	10.420	13.36	11.89
3	*Alstonia scholaris*	Apocynacecae	Native	213	3888.80	17.210	7.61	12.41
4	*Ficus virens*	Moraceae	Native	189	3660.73	16.200	6.75	11.47
5	*Saraca asoca*	Fabaceae	Native	123	418.98	1.850	4.39	3.12
6	*Polyalthia longifolia*	Fabaceae	Native	122	155.33	0.680	4.36	2.52
7	*Roystonea regia*	Arecaceae	Exotic	104	1687.09	7.460	3.71	5.59
8	*Morus alba*	Moraceae	Native	103	220.09	0.970	3.68	2.32
9	*Melia azedarach*	Melliaceae	Native	96	473.45	2.090	3.43	2.76
10	*Livistona chinensis*	Areaceae	Exotic	90	587.52	2.600	3.21	2.90
11	*Ficus binnendijkii*	Moraceae	Native	77	104.15	0.460	2.75	1.60
12	*Terminilia arjuna*	Combretaceae	Native	77	976.45	4.320	2.75	3.53
13	*Cassia fistula*	Fabaceae	Native	72	160.01	0.700	2.57	1.64
14	*Phoenix dactylifera*	Areaceae	Native	56	389.58	1.720	2.00	1.86
15	*Callistemon lanceolatus*	Myrtaceae	Exotic	55	105.62	0.460	1.96	1.21
16	*Diospyros malabarica*	Ebenaceae	Native	53	141.71	0.620	1.89	1.26
17	*Pongamia pinnata*	Papilionaceae	Native	44	105.48	0.460	1.57	1.01
18	*Haplophragma adenophyllum*	Bignoniaceae	Native	42	181.35	0.800	1.50	1.15
19	*Erythrina indica*	Fabaceae	Native	40	109.49	0.480	1.42	0.95
20	*Syzygium cumini*	Myrtaceae	Native	35	36.59	0.160	1.25	0.70
21	*Dalbergia sissoo*	Fabaceae	Native	33	135.80	0.600	1.17	0.89
22	*Eucalyptus crebra*	Myrtaceae	Exotic	31	324.12	1.430	1.10	1.27
23	*Ficus bengalensis*	Moraceae	Native	31	1654.28	7.320	1.10	4.21
24	*Thevetia peruviana*	Apocynacecae	Exotic	30	12.33	0.050	1.07	0.56
25	*Azadirachta indica*	Melliaceae	Native	30	66.05	0.290	1.07	0.68
26	*Bauhinia variegate*	Fabaceae	Native	27	28.97	0.120	0.96	0.54
27	*Mimusops elengi*	Sapotaceae	Native	26	28.73	0.120	0.92	0.52
28	*Putranjiva roxburghii*	Putranjivaceae	Native	20	8.97	0.030	0.71	0.37
29	*Bombax ceiba*	Malvaceae	Native	19	352.32	1.550	0.67	1.11
30	*Pinus roxburghii*	Pinaceae	Native	19	10.86	0.040	0.67	0.36
31	*Cebia speciosa*	Malvaceae	Exotic	19	9.76	0.040	0.67	0.36
32	*Leucaena leucocephal*	Mimosaceae	Exotic	18	10.49	0.040	0.64	0.34
33	*Ficus religiosa*	Moraceae	Native	18	19.74	0.080	0.64	0.36
34	*Delonix regia*	Fabaceae	Native	16	16.28	0.070	0.57	0.32
35	*Acacia nilotica*	Fabaceae	Native	15	13.30	0.050	0.53	0.29
36	*Albizia lebbeck*	Fabaceae	Native	13	42.81	0.180	0.46	0.32
37	*Mangifera indica*	Anacardiaceae	Native	12	18.43	0.080	0.42	0.25
38	*Lawsonia inermis*	Lythraceae	Native	9	4.59	0.020	0.32	0.17
39	*Bismarckia nobilis*	Arecaceae	Exotic	8	3.44	0.010	0.28	0.15
40	*Grevillea robusta*	Proteaceae	Exotic	8	0.47	0.002	0.28	0.14
41	*Nyctanthes arbor-tristis*	Oleaceae	Native	8	1.07	0.004	0.28	0.14
42	*Ficus carica*	Moraceae	Native	8	1.05	0.004	0.28	0.14
43	*Brachychiton acerifolius*	Malvaceae	Exotic	7	1.25	0.005	0.25	0.12
44	*Jacaranda mimosifolia*	Bignoniaceae	Exotic	7	7.89	0.030	0.25	0.14
45	*Pteropermum acerifoilum*	Malvaceae	Native	6	79.23	0.350	0.21	0.28
46	*Ficus elastica*	Moraceae	Native	6	39.50	0.170	0.21	0.19
47	*Ziziphus mauritiana*	Rhamnaceae	Native	4	0.65	0.002	0.14	0.07
48	*Cordia sinensis*	Boraginaceae	Native	3	0.81	0.003	0.10	0.05
49	*Ficus lyrta*	Moraceae	Native	2	0.29	0.001	0.07	0.03
50	*Tabebuia aurea*	Bignoniaceae	Exotic	1	0.01	0.00008	0.03	0.01
51	*Broussonetia papyrifera*	Moraceae	Exotic	1	0.01	0.00004	0.03	0.01
52	*Holoptelea integrifolia*	Ulmaceae	Native	1	0.33	0.00140	0.03	0.01
	Total			2798	22599.4			

*B.A: basal area, *SRD: species relative density, *SRD_0: species relative dominance, *IVI: important value index

Park had the lowest species richness of native trees (15). Jinnah Bagh also had the highest species richness of exotic trees (10), whereas Dhobi Ghat Park and Lyallpur Park had the lowest species richness of exotic trees (5).

Jinnah Bagh (628) recorded the most native trees, while Shahbaz Sharif Park recorded the least number of native trees (54). At Kaleem Shaheed Park, the most exotic plants were found (369), whereas at D Ground Park (41), the least exotic trees were identified. The maximum stand density of native trees was recorded at Lyallpur Park (113.47 trees/ha), while the minimum stand density of native trees was recorded at Shahbaz Sharif Park (8.92 trees/ha). The maximum stand density of exotic trees was recorded at Lyallpur Park (114.8 trees/ha), while the minimum stand density of exotic trees was recorded at D Ground Park (9.13 trees/ha) (Table 5).

Table 2. Comparison of different tree attributes (area, tree species richness, tree stand density) of selected urban parks of Faisalabad.

Urban Park tree Attributes	Old parks	New parks
Area of Parks (ha)	37.65	9.99
Tree species richness	47.00	36.00
Native species richness	34.00	24.00
Exotic species richness	13.00	12.00
Total tree count	2004.00	794.00
Native tree count	1355.00	325.00
Exotic tree count	649.00	469.00
Percentage of trees belonging to native species	67.61	40.93
Percentage of trees belonging to exotic species	32.38	59.07
Tree stand density per hectare	53.22	79.47
Native tree stand density /hectare	35.98	32.53
Exotic tree stand density /hectare	17.23	46.94

Table 3. Distribution and percentage of tree species on the basis family.

Sr.	Family	Number of tree species	Percentage of tree species (%)
1	Fabaceae	9	16.47
2	Moraceae	9	15.54
3	Araceae	4	9.22
4	Malvaceae	4	1.82
5	Bignoniacae	3	1.78
6	Combretaceae	3	29.59
7	Myrtaceae	3	4.32
8	Apocynaceae	2	8.68
9	Meliaceae	2	4.50
10	Anacardiaceae	1	0.42
11	Boraginaceae	1	0.10
12	Ebenaceae	1	1.89
13	Lythraceae	1	0.32
14	Mimosceae	1	0.64
15	Oleaceae	1	0.28
16	Papilionaceae	1	1.57
17	Putranjivacae	1	0.71
18	Pinaceae	1	0.67
19	Proteaceae	1	0.28
20	Rhamnaceae	1	0.14
21	Sapotaceae	1	0.92
22	Ulmaceae	1	0.03

Species richness of native trees (33) is higher in urban parks developed before 2010, while urban parks developed after 2010 represents lower native tree species richness (25). Exotic species richness (13) was also recorded a little more in urban parks established before 2010, as compared to exotic species richness (12) of urban parks established after 2010. Parks established before 2010 represents a higher proportion (67.61 %) of native tree species with exotic tree species contributing only (32.38 %). Parks established after 2010 represents a higher proportion (59.07 %) of exotic tree species with native tree species contributing only (40.93 %) (Table 2). The stand density of native trees (35.98 trees/ha) in parks established before 2010 was recorded higher, while parks established after 2010 represents slightly lower stand density of native trees (32.53 trees/ha). The stand density of exotic trees in parks established before 2010 was lower (17.23 trees/ha), while stand density of exotic trees in parks established after 2010 was recorded higher (46.94 trees/ha) (Table 2).

***Proportional distribution of tree Diameter at breast height (DBH)*:** In the present study, the diameter at breast height (DBH) of urban parks established before 2010 and after 2010 were studied. It was observed that in urban parks established before 2010 the tree DBH distribution class from 15 cm to 30 cm dominated the urban parks plantation. Diameter at breast height (DBH) class from 1 cm to 15 cm contributed (12.26 %) of the total tree population in parks established before 2010. From the origin point of view, DBH distribution class from 1 cm to 15 cm has (10.87%) native trees contribution while exotic trees contribute only (1.39 %). The DBH class from 15 cm to 30 cm accounts for (58.43%) of the total tree population in selected urban parks established before 2010. Native tree species dominated the DBH distribution class from 15 cm to 30 cm with a (33.43%) contribution, while exotic trees contributed (25.00%). In urban parks established before 2010 DBH distribution class from 30 cm to 45 cm accounts for (15.66%) of the total tree population. With reference to origin, native tree species dominated the DBH distribution class from 30 cm to 45 cm with (14.37 %) contribution, while exotic trees contributed only (1.29%). In urban parks established before 2010 DBH distribution class from 45 cm to 60 cm has (6.58%) contribution of the total tree population. Exotic tree species dominated the DBH distribution class from 45 cm to 60 cm with a (4.39%) contribution, while native trees contributed (2.19%). In urban parks established before 2010 DBH distribution class ≥ 60 cm contributed only (7.02%) of the total tree population. From origin point of view, native trees (6.18 %) dominated the DBH class ≥ 60 cm and exotic tree species contributed only (0.84%) (Fig. 3)

In urban parks established after 2010, It was observed that the tree DBH distribution class from 15 cm to 30 cm dominated the urban parks plantation. DBH class from 1 cm to 15 cm contributed (36.14 %) of the total tree population in parks established after 2010.

Table 4. Diversity indices (Shannon-Wiener diversity index, Shannon Evenness, Reciprocal Simpson's index) of the selected urban parks of Faisalabad.

	Name of Park	Shannon-Wiener diversity index (H)	Shannon Evenness (E)	Reciprocal Simpson's index (1/D)
Old Parks	Jinnah Bagh	3.21	0.81	16.63
	Kaleem Shaheed Park	2.73	0.80	10.46
	D Ground Park	2.65	0.86	9.38
New Parks	Lyallpur Park	2.10	0.68	4.62
	Shahbaz Sharif Park	1.66	0.56	2.88
	Dhobi Ghat Park	2.61	0.83	9.85
Average		2.49	0.75	8.97

Table 5. Species richness and tree stand density of native and exotic tree species in selected urban parks of Faisalabad.

Park Name	Area (Ha)	Species Richness	Native Species Richness	Exotic Species Richness	Total Tree count	Native Tree Count	Exotic Tree count	Native Tree stand density	Exotic Tree stand density	Percentage of native trees (%)	Percentage of exotic trees (%)
Jinnah Bagh	13.54	41	31	10	877	628	249	46.38	18.38	71.60	28.40
D ground Park	4.49	26	19	7	234	193	41	49.98	9.13	82.47	17.53
Kaleem Shaheed Park	19.62	30	21	9	893	524	369	26.70	18.80	57.89	42.11
Lyallpur Park	1.41	22	17	5	321	160	161	113.47	114.18	50.15	49.85
Shahbaz Sharif Park	6.05	22	15	7	266	54	212	8.92	35.04	20.31	79.69
Dhobi Ghat Park	2.53	23	18	5	207	110	97	43.47	38.33	53.14	46.86
Total					2978	1656	1142				

Table 6. Stem count was used to calculate diversity benchmarks for tree inventories in selected urban parks. The species, genus, suggested 10/20/30 benchmark is shown in bold in the data. All others fell short of the suggested benchmark.

Road Name	Age Category	Dominant Species Origin	Stem Count	Most abundant species (%, Name)	Most Abundant Genus (%, Name)
Jinnah Bagh	Old	Native	877	16.98% *Alstonia scholaris*	**16.98 %, *Alstonia***
D ground Park	Old	Native	234	28.20 %, *Ficus virens*	34.61 %, *Ficus*
Kaleem Shaheed Park	Old	Exotic	893	23.18 % *Terminalia ivorensis*	29.56 %, *Terminalia*
Lyallpur Park	New	Exotic	321	41.10 % *Conocarpus erectus*	41.10 %, *Conocarpus*
Shahbaz Sharif Park	New	Exotic	266	55.63 %, *Conocarpus erectus*	55.63 %, *Conocarpus*
Dhobi Ghat Park	New	Exotic	318	23.67 % *Terminalia ivorensis*	23.67 %, *Terminalia*

From the origin point of view, DBH distribution class from 1 cm to 15 cm has (19.52%) exotic trees contribution while native trees contributed (16.62%). The DBH class from 15 cm to 30 cm accounts for (46.47%) of the total tree population in selected urban parks established after 2010. Exotic tree species dominated the DBH distribution class from 15 cm to 30 cm with a (26.95%) contribution, while native trees contributed (19.52%). In urban parks established after 2010 DBH distribution class from 30 cm to 45 cm accounts for (14.47%) of the total tree population. With reference to origin, native tree species dominated the DBH distribution class from 30 cm to 45 cm with (9.94 %) contribution, while exotic trees contributed only (4.53%). In urban parks established after 2010 DBH distribution class from 45 cm to 60 cm has (2.26%) contribution of the total tree population. Exotic tree species dominated the DBH distribution class from 45 cm to 60 cm with a (1.76%) contribution, while native trees contributed (0.5%). In urban parks established after 2010 DBH distribution class ≥ 60 cm contributed only (0.62%) of the total tree population. From origin point of view, native trees (0.62 %) dominated the DBH class ≥ 60 cm and exotic tree species has no contribution (0.00%) (Fig. 2).

***Diversity Indices*:** The Shannon-Weiner index (H) value for the current research ranged from (1.66) to (3.21), with an average of (2.49). Jinnah Bagh has the highest Shannon-Weiner index (H) value (3.21), followed by Kaleem Shaheed Park (2.73). Shahbaz Sharif Park (1.66) has the lowest value of Shannon-Weiner index (H). Shannon's evenness index (H_E) varied from (0.56) to (0.86) with an average of (0.75). The lowest HE is at Shahbaz Sharif Park (0.56), and the highest HE is at Jinnah Bagh (0.86). Reciprocal Simpson's Index (1/D) varied from (2.88) to (16.63) with an average value of (8.97). The highest 1/D value was recorded in Jinnah Bagh (16.63), followed by Kaleem Shaheed Park (10.46), while the lowest 1/D value was recorded at Shahbaz Sharif Park (2.88). Maximum value of Shannon-Weiner index (H) (3.21), Shannon's evenness index (H_E)(0.86) and Reciprocal Simpson's Index (1/D)(16.63) was recorded in Jinnah Bagh (3.21) which was established before 2010, while minimum value of Shannon-Weiner index (H) (1.66), Shannon's evenness index (H_E)(0.56) and Reciprocal Simpson's Index (1/D)(2.88) was observed at Shahbaz Sharif Park (1.66) which was established after 2010 (Table 4).

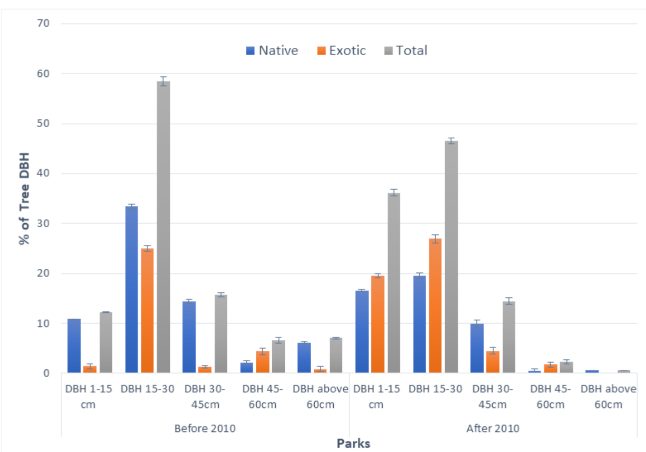

Figure 2. Proportional distribution of tree diameter at breast height (DBH) (1-15cm, 15-30cm, 30-45cm, 45-60cm, and above 60cm) on selected urban parks of Faisalabad on the basis of parks established before and after 2010

***Diversity benchmark (10/20/30) of selected urban park tree Species*:** In the present study, tree species, genus, or families that met the proposed 10/20/30 benchmark was tested on the selected urban parks of Faisalabad. Results indicated that all the urban parks failed to meet the 10% benchmark of single tree species. Jinnah Bagh with (16.98%) of *Alstonia scholaris* was close to reaching the proposed 10% benchmark of single species whereas all the other selected urban parks were far away from meeting the criteria of the purposed benchmark of 10%. Shahbaz Sharif Park with (55.63 %) *C. erectus* was highly far away to meet the purposed 10% benchmark. Among all the urban parks only, Jinnah Bagh meets the purposed 20% benchmark at the genus level with (16.98 %) of plant species from the genus *Alstonia*. Shahbaz Sharif Park with genus *Conocarpus* (55.63 %) was highly far away to meet the proposed 20% benchmark. All the urban parks failed to meet the purposed criteria of 30 % of plant species belonging to a single family. Jinnah Bagh showed (16.98 %, Apocynaceae) lower values, while all the other urban parks showed higher values for the single-family than the proposed 30% benchmark. Overall, selected urban parks failed to meet the purposed benchmark (10/20/30). From the origin point of view, two older parks showed the dominance of native plant species while all the new parks showed the dominance of exotic plant species (Table 6).

DISCUSSION

Faisalabad is widely well-known as one of the biggest industrial cities in Pakistan. Faisalabad's urban environment and ecosystem are little understood despite its growing prominence as a global city. Species richness can be a useful index to assess the diversity level of the studied area. We found that Faisalabad's parks have a species richness of 52 species recorded in six Urban parks, consisting of 2,978 trees. Urban Parks developed before 2010 have higher species richness (47), while the parks established after 2010 have a lower species richness (36). Therefore, it demonstrated that the time scale had a substantial influence on the species richness. A similar study conducted by (Xie, 2018) reported 80 tree species in the parks of Dublin, Ireland. (Muthulingam and Thangavel, 2012) recorded 45 tree species in urban green spaces in Chennai, India. There were 111 historical tree species and 162 recent tree species in the parks of Bandung (Abendroth *et al.*, 2012), whereas there were 80 tree species from Bangalore parks, India (Nagendra and Gopal, 2010); another similar study recorded 110 tree species in Turku, 61 tree species in Stockholm, 196 tree species in Malmo, 60 tree species in Gothenburg and 559 tree species in Arhus from the Nordic cities (Sjöman *et al.*, 2012); In Flanders (the northern part of Belgium), 15 urban and suburban parks had average plant taxa 136.8 (including herbaceous plants) (Cornelis and Hermy, 2004). It was found by comparison that tree species richness was deficient in the urban parks of Faisalabad.

Only a few species dominated the tree distribution in our survey. According to the findings, the top six tree species account for nearly half of all trees in the study. Our results depicted that old parks have a higher percentage of native trees (67.61%) but the percentage of exotic trees (59.07%) was higher in new parks. It clearly indicates that if this plantation trend continues soon major portion of plantations will consist of exotic tree species, which will result in the loss of native tree species. Our results showed the presence of a higher percentage of exotic species, whereas Maurer *et al.* (2000) reported a higher percentage (81%) of native trees in a study conducted in Postdam. In research done in the parks of the Korean city of Chonju (Zerbe *et al.,* 2004) found that exotic species account for just 30% of the overall plant population. Although exotic tree species contribute to enhance tree diversity, but their overplanting causes various ecological imbalances. Urban forests are a unique combination of native and exotic species (Garcillán *et al.,* 2009). Most preference for exotic species is given due to their foliage and flowering beauty (Dos Santos *et al.,* 2010). Some researchers suggested that a combination of introduced and native species is helpful to biodiversity in some ways (McIntyre and Hobbs, 1999; Hunter, 2007), however, it is apparent that the presence of a significant number of exotic species would fundamentally affect ecosystem structure and function (McKinney, 2006). As a result, there appears to be a drive in some places, such as Phoenix, to grow native plants (Martin *et al.,* 2004). The significant dominance of exotic tree species in urban parks established after 2010 in Faisalabad appears to be leading to park flora homogeneity. The dominance of exotic plant species is an alarming trend when combined with previous study findings that imply that exotic plant species have a severe influence on the distribution of other taxa, notably birds (Mills *et al.*, 1989; Khera *et al.,* 2010). Recent planting has followed this pattern, with a focus on exotic tree species like *Terminalia ivorensis* and *Conocarpus erectus*, with just two native species, *Ficus virens* and *Alstonia scholaris*, being planted in substantial quantities in recent years. Our findings reported a higher tree diversity in parks established before 2010 as compared to parks established after 2010. Similar results have been reported for the old parks in Beijing to have greater plant diversity by Weifeng *et al.* (2006) and in the vicinity of Berlin (Maurer *et al.,* 2000). Owing to the long history of the old park and having been founded at various times and managed by a variety of park administrators, it results in more heterogeneous and diversified growth.

According to Deb *et al.* (2013), the distribution of diameter at breast height (DBH) size class explains that the tree species cultivated over a long time should have a more evenly distributed age structure, while the tree species cultivated recently should be dominated by smaller trees, and the tree species planted widely and discontinuously in the past and recently should be dominated by larger trees. Our results showed the domination of the diameter at breast height (DBH) distribution class from 15 cm to 30 cm, which indicates that tree species present in urban parks established before 2010 were of moderate age. Whereas in parks established after 2010, DBH distribution classes from 15cm to 30cm showed domination. In parks established before 2010, native trees showed domination in DBH distribution classes except in DBH distribution class (45 cm to 60 cm). It shows that native tree species were preferred along with exotic tree species, but in the case of parks established after 2010, exotic tree species domination in the DBH distribution class (45 cm to 60 cm) was evident. The parks established after 2010 showed a completely opposite plantation pattern to those established before. DBH distribution suggests that if the current plantation trend continues in urban parks, it may result in the extinction of native tree species, disrupting the ecological functioning of the urban environment.

The structure of the biological community was presented in terms of numerical value using a diversity index, a tool for biologists to understand community structure (Muthulingam and Thangavel, 2012). Lower diversity of plant species may be vulnerable to resistance to diseases and pests as compared to areas with higher plant diversity (Zhang and Jim, 2014). The range of the Shannon-Wiener diversity index was 2.65-3.21 (average 2.86) and 1.66-2.61 (average 2.12) in parks established before 2010 and after 2010, respectively. It was recorded that the average of Shannon-Wiener diversity index was 3.76 in the parks of Taipei, China (Jim and Chen, 2009), but only about 1.0 in the parks of Bangalore, India (Nagendra and Gopal, 2011); in the parks of Roxbury and Dorchester, MA, America, the average was 1.65; within urban parks of Halifax regional municipality (Nova Scotia, Canada), the Shannon-Wiener diversity index ranged from 1.2 to 2.6 between semi-natural habitats and anthropogenic habitats (Lapaix and Freedman, 2010). Compared with these cities, the diversity of urban parks in Faisalabad fell to a medium level, which was consistent with species richness. The range of the Shannon evenness index was 0.80-0.86 (average 0.82) and 0.56-0.83 (average 0.69) in parks established before 2010 and after 2010, respectively. Parks established before 2010 showed greater evenness than reported in various studies conducted in Taipei (0.74) (Jim and Chen, 2009) and Chennai (0.73) (Muthulingam and Thangavel, 2012) but parks established after 2010 have reported lower diversity when compared with the above studies. The range of reciprocal Simpson's index (1/D) was 9.38-16.63 (average 12.15) and 2.88-9.85 (average 5.78) in parks established before 2010 and after 2010, respectively. Through comparison of reciprocal Simpson's index (1/D), we can comment that parks established before 2010 have great diversity but after 2010 the parks have lower tree diversity. The study's finding of a low species evenness shows that some species, the majority of which are exotic, nevertheless dominate tree populations. Different Asian cities including Guangzhou (Jim and Liu, 2001), Beijing (Li *et al.,* 2006), Bangalore (Nagendra and Gopal, 2010), and Shenzhen (Ye *et al.*, 2012) have all documented similar trends.

A commonly used rule of thumb is the 10/20/30 benchmark proposed by Santamour (1990), which states that urban forests should comprise no more than 10% of any particular species, 20% of any one genus, or 30% of any single family. There were significant differences in observed patterns of diversity and the diversity benchmarks proposed by Santamour (1990) in the selected urban parks of Faisalabad. In comparison to the purposed benchmark, our results in terms of relative abundance at species, genus, and family levels were generally higher. Due to a lack of clear policy for urban plantation in Faisalabad, the plantation of all the selected urban parks was deviating significantly from the purposed benchmark. According to Kendal *et al.* (2014), the purposed benchmark of 10/20/30 is difficult to achieve in urban forests. The main aim of the purposed benchmark was to enhance the diversity of urban forests in order to improve the ecological functioning of urban areas.

Change in time also impacted the diversity pattern of urban parks in a negative sense leading towards decreased diversity of urban trees which will ultimately disturb the health of the ecosystem and will result in the loss of tree species. To improve diversity, the municipal department concerned should not only increase the number of trees but also take the number of tree species into account. Unfortunately, the city lacks a unified, publicly accessible tree policy that explains which species to plant and for what purposes. City Park trees should be selected with greater attention, not just for the sake of simple and easy maintenance, as is the case presently, but also to support other biodiversity and provide environmental and ecological benefits.

Conclusion**:** Urban parks were of great significance for the entertainment of urban dwellers, but there were more important to the urban ecosystem. The tree species composition, diversity, native, and exotic tree distribution in 6 urban parks of Faisalabad were discussed, while the difference between OP and NP was also assessed to find the influence of time scale on the different categories' parks. By comparing the species richness of the two kinds of parks, the time scale markedly affected both categories of parks. For the municipal department of Faisalabad, multiple measures should be undertaken to improve tree diversity. For park design and maintenance, park administration should look for more diversity than the already prevalent trees. Specifically, park administrators should consider increasing the percentage of flowering trees and evergreen trees and promoting landscape diversity in the future. Furthermore, exotic tree species cannot be completely excluded from urban greening due to their important role in improving the diversity of urban plantations. Besides, the departments concerned should learn the inventories and tree selection experience from other European countries. Some components of biodiversity may benefit from a combination of exotic and native species. Therefore, on the premises of risk assessment, the appropriate introduction of tree species to enrich the urban biodiversity was more helpful.

Author contribution statement**:** All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Muhammad Umair Shafique, Adnan Younis, Muhammad Asif, and Mansoor Hameed. The first draft of the manuscript was written by Muhammad Umair Shafique and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest**:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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