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Research Article

Investigating the Urban trees' diversity in Tehran –Iran using i-Tree Eco model

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Abstract

Urban green spaces' structure and function can promote human health and environmental quality and also decrease some challenges that have been increased due to urbanization. So, it is important to do some studies to investigate the urban trees' diversity and structure because it can not only raise environmental awareness but also help policymakers for better management to achieve the desired environment. According to our knowledge, there has been done no investigation on the diversity of the urban trees of Tehran. The present study aims to assess the current structure and diversity of trees in Tehran green spaces (as a case study), using the i-Tree Eco model. Data from 316 field plots were collected during the growing season. It must be noted that the primary number of plots was 330, but some of them were not accessible. The plots were selected based on a randomized cluster sampling method and analyzed using the i-Tree Eco model. The results indicate that the overall tree density in Tehran is about 97 trees/ ha and the number of trees is about 7,127,933. The most common tree species are Afghan pine (13.0 percent), Black locust (10.0 percent) and, Arizona cypress (9.4 percent). In Tehran, about 28 percent of the trees are Asian endemic species and most trees have American origin (26 percent of the trees). Tehran urban trees are composed of endemic and exotic tree species. Therefore, Tehran's urban forest often has a diversity that is higher than the surrounding native landscape. Thus, the paper illustrates a methodology to assess the current structure and trees' diversity of urban forests, which helps the development of future urban tree planting strategies and quantitative assessment.

Keywords: i-tree Eco model, Trees diversity, Urban green spaces

Introduction

Trees, as prominent elements of urban green spaces, play an important role in providing economic, social, and environmental benefits, including physical and mental health, aesthetic values, recreation, climate regulation, air quality, carbon sequestration, stormwater runoff reduction, all of which contribute to human well-being (Chinchilla et al., 2021; Wang et al., 2016; Nyelele and Kroll, 2020; Riley et al., 2017; Zięba-Kulawik et al., 2021; Wood and Dupras, 2021; Fan et al., 2019; Jiao et al., 2021; Dangulla et al., 2020). Urban trees refer to all public and private trees in urban areas, including individual trees along streets and remnant forest stands. They are either natural or planted and usually have a single stem and distinct canopy (Roy et al., 2012).

Urban forests formed by urban trees compose an important part of urban landscapes and can be considered a land use that creates space for trees (Fan et al., 2019). Urban forests and their related ecological processes play an important role in the structure, function, and dynamics of urban ecosystems (Wang et al., 2016). In other words, urban forests are an essential element for the sustainable functioning of cities in the face of economic and social changes and increasing urbanization leading to the formation of megacities.

Like other natural systems, the function and stability of urban forests depend on the species composition of their communities (Nowak et al., 2016). Species diversity of urban forests, considered as different species in an area, is the main component of urban biodiversity (Yan and Yang, 2017). Species diversity plays a crucial role in the functioning and maintenance of urban forest stability (Li et al., 2020; Morgenrot et al., 2016). Species diversity is also important for the resilience of urban forests so that higher species diversity is expected to have greater stability in ecological function (Wood and Dupras, 2021; Fan et al., 2019).

Diversity can protect urban forests from pests and diseases, climate change, and other adverse environmental conditions (Wang et al., 2021; Dangulla et al., 2020; Paquette et al., 2021). There is also a link between species diversity and the provision of ecosystem services. An urban forest with high species diversity can provide various ecosystem services (Yan and Yang, 2017; Kendal et al., 2014; Nowak et al., 2016; Jiao et al., 2021; Blood et al., 2016. Thus, the amount and diversity of trees are important indicators of the quantity and quality of ecological services provided by trees. Evaluating urban tree diversity is a key step in managing and planning urban ecosystems resulting in the improvement of ecosystem services and the urban environment. Lack of tree diversity can put urban forests at risk of biotic and abiotic stressors (Ma et al., 2020).

Although species diversity can optimize multiple ecosystem services and ensure the stability of urban forests in the face of disturbance, increasing species diversity cannot guarantee the enhancement of ecosystem function. Some species, such as invasive species or exotic species, can

be undesirable and may cause damage. Therefore, it is essential to adopt adequate strategies to optimize desirable ecosystem services and reduce disservices (Morgenrot et al., 2016).

The importance of studying species composition and diversity in urban landscapes is well recognized for planning and management purposes (Dangulla et al., 2020; Morgenroth et al., 2016). Accordingly, many studies have investigated the abundance and diversity of urban trees due to their potential to alleviate environmental degradation and benefit for city dwellers (Jiao et al., 2021; Dangulla, 2020; Chinchilla et al., 2021; Roy et al., 2012).

Urban forests are not static and change over time due to natural factors (e.g., insects and diseases, storms) and human factors (such as development, land-use change, and management strategies) (Nowak et al., 2016; Riley et al. al., 2017; Chimaimba et al., 2020). Land-use change is one of the driving factors affecting biodiversity (Li et al., 2020). Other drivers of urban tree species composition and diversity include urbanization levels and physical and demographic characteristics (Chimaimba et al., 2020). Urbanization leading to landscaping homogenization is often the main reason for the decline in biodiversity and native species (Wang et al., 2016; Pyles et al., 2020).

Land-use change and urbanization adjacent to urban areas have led to an alteration in the composition and structure of urban forests. Around half of the world's population lives in cities, and 10% live in megacities, which will increase up to 75% by 2050 (Roy et al., 2012). Many cities have experienced unpredictable growth along with environmental degradation, including habitat and biodiversity loss, soil erosion as well as carbon and noise pollution (Roy et al., 2012). The impact of urban growth on the environment is complex, ranging from structural changes to the loss of ecosystem function and reduction of ecosystem services provision (Grêt-Regamey et al., 2017). Therefore, understanding the diversity of urban trees and the factors influencing them can help decision-makers plan and manage urban trees more effectively and optimize the structure and species diversity of urban forests.

In Iran, two studies have been done on the UF of the Khorasan-e-Razavi and Eastern Azerbaijan provinces so far (Parsa, 2019). According to our knowledge, the diversity of green spaces' trees in Tehran has not been investigated and this is an important shortcoming in environmental studies in Tehran. Similar to many large cities, Tehran is experiencing urban expansion and population growth, resulting in changes in urban ecosystems' structure and function. Such processes highlight the significance of urban trees' diversity studies as an important contributor to the sustainability of urban ecosystems addressed in this paper. This study aims to investigate the structure and diversity of native and exotic tree species in Tehran. The findings of our study can contribute to a better understanding of urban trees' diversity and improvement of urban forest planning and management.

Materials and method

Study area

The present study was done within the municipal administrative borders of Tehran city, the capital of Iran (Fig. 1). Tehran is divided into 22 regions and is located in the center of Iran (35° 31' to 35° 57' N, 51° 4' to 51° 47 ' E) with an area of about 60,000 ha and a population of 8.7373.510 People in 2016 ((Statistical Center of Iran, 2016; Tehran statistical yearbook, 2018). Since the city of Tehran has a special geographical location (the elevation in the north is much higher than in the south), it has different climatic conditions, ranging from Semi-humid in the north to arid and semi-arid in the south (Tehran statistical yearbook, 2018). The growing season in Tehran lasts from April to September and is about six months. The annual wind speed is about 16 knots. The annual mean precipitation is about 57 mm, which is mostly during March and April. The city has about 5213 ha of green space (Tehran statistical yearbook, 2018).

Figure 1. Location of the study area

i-Tree Eco-6 model

In the present study, we used the i-Tree Eco model, since, among several In-tree analysis tools and utility programs (such as i-Tree Eco, and i-Tree Pest Detection Module), i-tree Eco is the most suitable one for international projects (Kiss et al., 2015; Parsa et al., 2019) and provides detailed data required by urban managers to make sustainable decisions on urban forest (Nowak, 2013). The model can estimate the urban forest structure (Species composition, number of trees, tree density, etc) ((i-Tree Eco User's Manual, 2021). Since the i-Tree model was developed for the US, conducting urban forest projects outside the US requires additional data collection such as location information (e.g. continent, nation, latitude, longitude, elevation mean minimum temperatures, ozone state, etc), precipitation data (e.g., weather station, precipitation data, etc.) and air pollution data.

Field data collection

A randomized-cluster sampling method was applied to determine the spatial location of sampling plots. For this purpose, the first step was to divide Tehran into smaller units based on land use similarity and was reclassified into five classes, namely commercial and industrial, green spaces or parks, residential, transportation, and other (Table 1). The original land use map was obtained from Tehran municipality (for the year 2017, with 1:25,000 scales) and updated using field studies. Regarding previous studies (Parsa et al.,2018; Intasen et al., 2017; Nowak et al., 2017; Mikulanis, 2014; PARD, 2014; Pace and Sales, 2012; Nowak et al., 2011) and i-Tree Eco users' manual "As a general rule, 200 plots(one-tenth acre each) in a stratified random sample with at least 20 plots per stratum will yield a standard error of about 10% for an estimate of the entire city " (i-Tree Eco User's Manual, 2021), a total of 330 plots were selected and sampled with a radius of 11.34 m during the growth season (from 9th May 2020 to 20th September 2020). To determine the number of sample plots for each land-use class, a questionnaire was distributed to 30 environmental experts to score each land use based on interest, possibility, and potential for the existence of trees within each land-use class from 0 to 10 (10 being more interested). Using the questioners WOI and RWOI were obtained (Table 1).

Table1. Number of plots used in the study

land use classes	Area(ha)	Area (%)	WOI	RWOI	Number of plots
Commercial /Industrial	3375.07	6	0.708	0.17	20
Green spaces (parks)	5,213.35	9	0.972	0.23	42
Residential	25732.72	43	0.67	0.16	141
Transportation	15706.1	26	0.59	0.14	76
Other	8,996.11	16	0.69	0.16	51
overall	59023.35	100.00	-	1	330

The Weight of Interest (WOI) indicates the average level of interest provided by the environmental experts (Environmental sciences Ph.D. candidates and academic staff of the Shahid Beheshti University, Tehran, Iran). The RWOI (Relative Weight of interest) was calculated by multiplying WOI by the area percentage of each class. Finally, RWOI was multiplied by the final number of plots (330) to obtain the number of plots for each land-use class (Table 1). Water bodies (artificial lakes) were omitted from the analyses because only terrestrial ecosystems were taken into account. Figure 2 illustrates the spatial distribution of plots throughout Tehran regarding the land use classes.

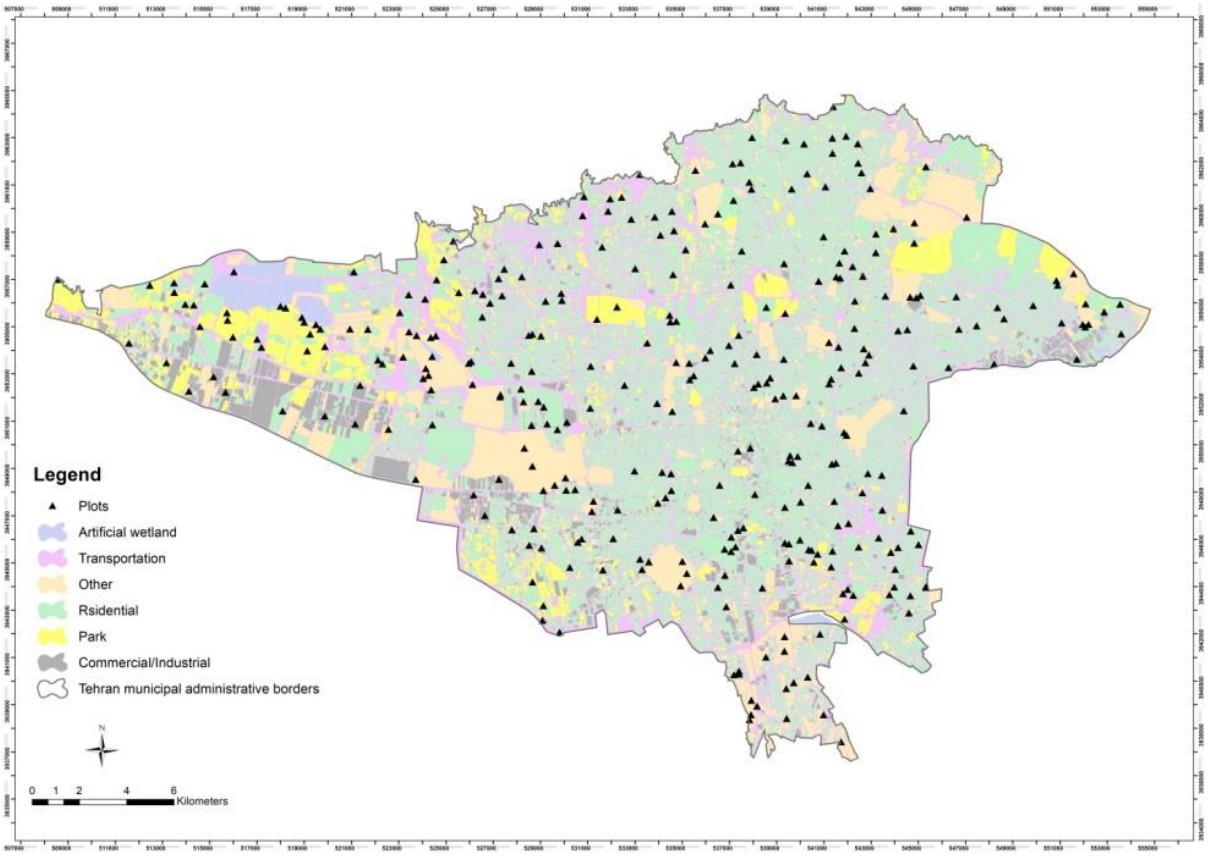

Figure 2. Spatial distribution of sampling plots thought the municipality borders of Tehran regarding the land use classes (Source: Land use map obtained from Tehran municipality)

All data on the plots' trees were collected for each plot (Table 2). i-Tree Eco model uses the survey data to assess the urban forest structure through the composition and structure module. This module provides information on the summary of the structure by species and stratum (e.g., the number of trees, leaf area, etc) (i-Tree Eco User's Manual, 2021; Nowak, 2019; Parsa et al., 2019).

Table 2. Measured variables in the fieldwork

Trees	Plots
• Species • DBH • Dead or alive • Status (planted, ingrowth, unknown) • Distance to the plot center • Direction to the north • Land use in which the given tree was located • Crown heath • Total tree height • Crown base height • Crown width (N-S and E-W) • Crown missing • Land cover under the canopy • Crown light exposure	• Percent measured • Percent tree's canopy cover • Land use • plot address

Results

Based on the results, the urban forest of Tehran has an estimated 7,127,933 trees (±370,364, the standard error of about 5.19%) with a tree cover of 32.6 percent. The three most common species are Afghan pine (13.0 percent, 928,223 trees), Black locust (10.0 percent, 711,562 trees), and Arizona cypress (9.4 percent, 666,802 trees). While, in another city in Iran, Tabriz, the three dominant tree species are Robinia pseudoacacia (12.5%), Fraxinus excelsior (9.8%), and Elaeagnus Angustifolia(8%) (Parsa et al., 2019). This difference is due to the climatic and administrative management differences. Figure 3 illustrates the percentage of dominant tree species in Tehran.

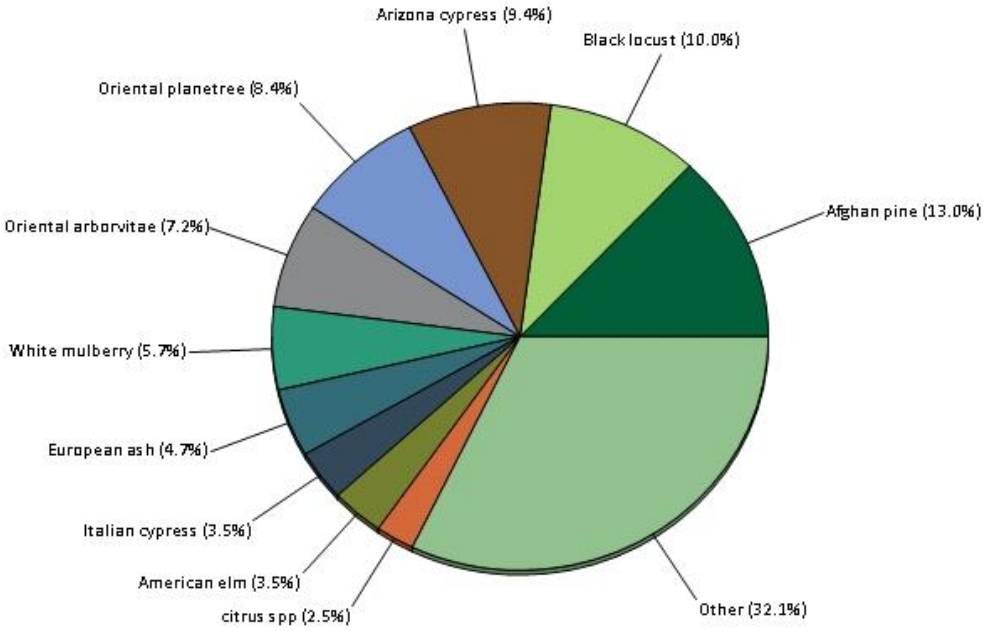

Figure 3. Tree species composition in Tehran (Source: Based on the research findings)

The overall tree density in Tehran is about 120.76 trees/ha (5.19 % SE). As expected, the highest tree densities in Tehran occur in the green infrastructure (park) stratum, followed by the Commercial/Industrial (175.28 tree/ha) category (Fig. 4). This result is almost similar to the finding of Tabriz (a city in northwest Iran) (Parsa et al, 2019).

Table 3. Tree population summary by land-use classes (Strata)

land use classes	Number of trees	SE (%)	Percentage (%)	Tree density (tree/ha)	Leaf area (ha)
Commercial / Industrial	913,753	15.7	12.82	175.28	5,054.283
Green Spaces (park)	1,389,285	6.9	19.50	266.48	8,539.659
Residential	2,582,406	9.4	36.22	100.35	11,709.126
Transportation	956,334	7.44	13.41	60.89	4,360.707
Other	1,286,156	16	18.05	142.97	4,577.839
Study area	7,127,933	5.19	100	120.76	34,241.615

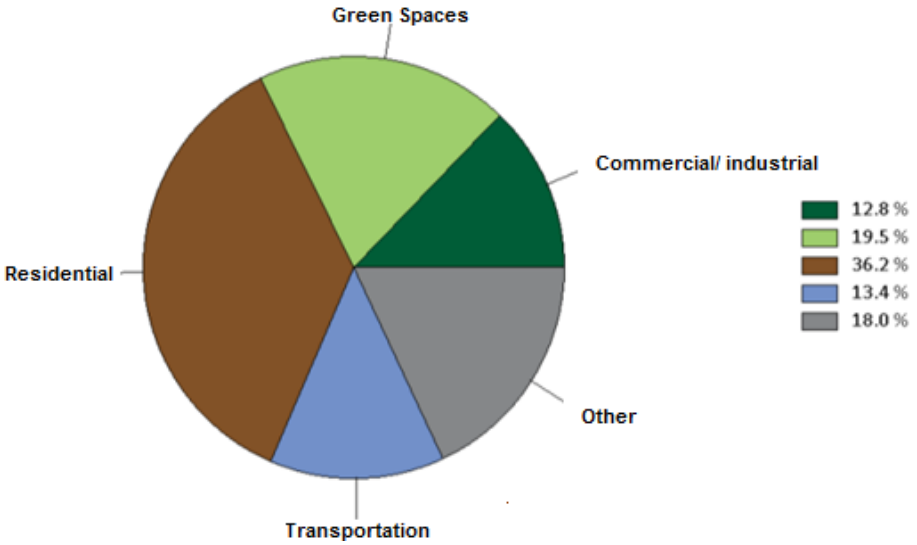

Figure 4. Percentage of trees in Tehran by stratum (Source: Based on the research findings)

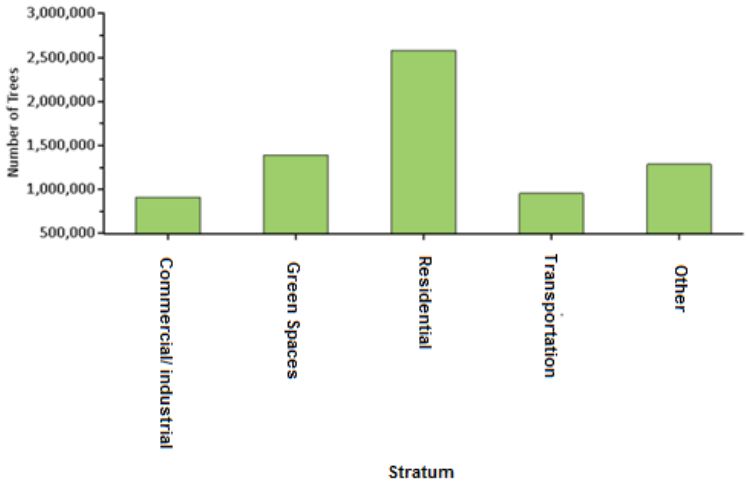

Figure 5. Number of trees in Tehran by stratum

As figure 6 indicates, Tehran's urban green infrastructure is composed of a mix of native and exotic tree species. Thus, it often has a tree diversity that is higher than surrounding native landscapes.

Discussion

Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. No invasive species were found among the Tehran urban green spaces trees. In Tehran, about 28 percent of the trees are species native to Asia. Most trees have an origin in North America (26 percent of the trees). Having a mixed native and exotic species of trees and a, therefore, higher level of trees diversity is valuable since it can provide more diverse ecosystem services as the quantity and monetary value of ecosystem services provided by the urban forest exotic species was greatest in inner-city vacant lots, while native taxa provided more monetary value on residential lots in Cleveland, OH (Riley et al., 2018).

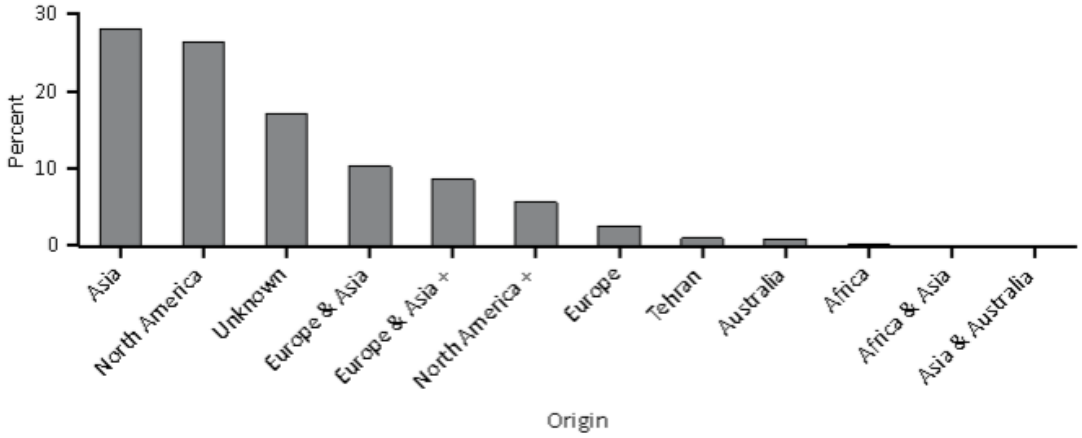

Figure 6. The percent of live tree population by area of native origin, Tehran (Source: Based on the research findings). The plus sign (+) indicates the tree species is native to another continent other than those listed in the grouping.

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 32.6 percent of Tehran and provide 342.4 square kilometers of leaf area. Total leaf area is greatest in Residential (about 115 Km^2) followed by green spaces (parks) (80 Km^2) (Fig.7).

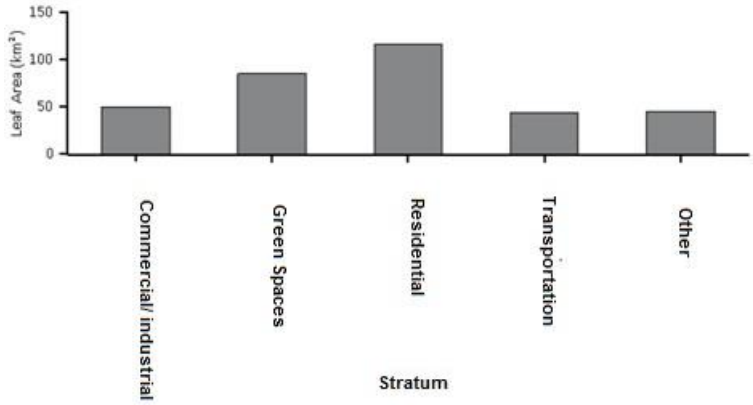

Figure 7. Leaf area by stratum, Tehran (Source: Based on the research findings)

In Tehran, the most dominant species in terms of leaf area are Afghan pine (27.1%), Oriental plane tree (8.4%), and Arizona cypress (9.4%). The 10 species with the greatest importance values are listed in Table 3. Importance values (IV) which show the species
currently dominating the urban green structure are calculated as the sum of percent population and percent leaf area. High importance values do not necessarily mean that these trees should necessarily be encouraged in the future (i-Tree Eco User's Manual, 2016; Nowak, 2019, Parsa, 2019).

Table 4. Leaf area of the most common species (Source: Based on the research findings)

Species Name	Percent Population	Percent Leaf Area	IV
Afghan pine	13.0	27.1	40.1
Oriental plane tree	8.4	18.9	27.2
Arizona cypress	9.4	6.9	16.2
Black locust	10.0	4.7	14.7
European ash	4.7	5.2	9.9
Oriental arborvitae	7.2	2.5	9.8
American elm	3.5	4.6	8.1
White mulberry	85.7	2.2	7.9
Italian cypress	3.5	1.9	5.4
Elm spp	2.3	3.0	5.3

Based on the results (Table 5), similar to Tabriz, the highest species richness belonged to the green infrastructure category (Parsa et al., 2019). In Tehran, urban green spaces with a Richness Index of 58 and the Transport category with a Richness Index of 38 have the highest and the lowest species richness, respectively. The residential category had the highest values for almost other indices. Evenness is almost identical (about 0.8) for all land use classes.

Table 5. Tehran trees' diversity indices (Source: Based on the research findings)

Stratum	Richness	SPP/ac	Shannon	Menhinick	Simpson	Evenness	Rarefaction
Commercial /Industrial	25	7.8	2.8	2.3	14.4	0.9	23.5
Green spaces (Parks)	58	10.9	3.1	2.5	15.6	0.8	27.9
Residential	50	5.1	3.3	2.5	19.7	0.8	30.1
Transport	38	4.2	2.8	1.9	12.1	0.8	21.8
Other	33	7.9	2.7	2.1	10.5	0.8	22.9
Study Area	97	7.6	3.3	2.4	16.4	0.7	N/A

*Richness: is the number of species in each stratum (i.e., species richness)
*SPP/ac: is the number of species found per acre of the study area

Conclusion

Having good knowledge about the urban trees' diversity can help managers promote human welfare, reduce the cities' issues, and plan future development projects (Xiaoting et al, 2020). We investigate the current structure and diversity of Tehran green spaces' trees based on five land use classes. Our research also illustrates the most common tree species in Tehran, namely Afghan pine, Black locust, and, Arizona cypress is not original to Iran or even Asia that must be noted in future planting practices. For further research, it is recommended to assess the current and particularly possible future air quality improvements and other ecosystem services urban trees as well as uncertainty analysis.

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