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Article

Structure, diversity and spatial distribution pattern of significant tree species in Hefei city

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Abstract: In order to further tap the ecological potential of urban trees, improve the diversity of tree species in urban environment, and promote the sustainable development of urban trees, this paper further analyzes the structure, diversity and spatial distribution law of the prominent tree species in Hefei city on the basis of on–the–spot identification of the prominent trees distributed in the main city. The results show that: 1) 528 significant trees are identified in the three districts, belonging to 40 species, 36 genera and 27 families, with 23 trees evaluated by qualitative index and 505 trees by quantitative index. In quantity distribution, the number of significant trees in the three districts is ranked as Yaohai District > firstringroad City > Government Affairs District. The top four tree species in relative abundance are Platanus acerifolia, Cinnamomum camphora, Ginkgo biloba and Cedar. 2) In terms of the tree age structure, most trees are 20–40 years old, and only 22 trees are over 100 years old; the ratio of evergreen to deciduous tree species is 1:3, and the ratio of plant to tree is about 7: 18; there are 23 native tree species accounting for 57.50%, but only 171 trees. 3) In terms of area distribution, the average tree height and crown area in Yaohai District are the largest, the average DBH, Shannon–Wiener index and Simpson index in the first–ring city area are the highest, and the species evenness index in Government District is the highest. 4) In terms of site types, most significant trees are distributed in urban streets, residential areas and parks, and only 11.74% of them are distributed in government organizations, schools, public facilities, scenic spots and religious land.

Keywords: urban forest; significant tree; tree species diversity; spatial distribution; Hefei city

1. Introduction

Prominent trees refer to trees with large volme, beautiful tree shape, important location, rare species, eye-catching and outstanding vision, which are highly concerned and loved by the public, or have high historical and cultural connotation and aesthetic value [1]. Since the 21st century, the demand for ecological green has been increasing in the process of urban development, and trees have become the symbol of urban green ecology. In many parts of the world, including North America, Europe and China, relevant urban managers and decision makers have gradually attached importance to urban greening ecological construction when formulating urban development plans, and implemented a series of large-scale greening construction measures. However, cities are not a friendly environment for trees. Most trees cannot give full play to their biological potential [2–5] under the urban background, and their landscape and ecological benefits need to be explored and improved. Most scholars believe that the protection and management of rare or significant trees in the urban environment should be strengthened to maximize their

landscape ecological value. The research on urban trees also involves many aspects, such as protection strategies [6–8], changes in floristic composition, growth mechanism [9–12], ancient and rare trees [13–16]. However, there is a lack of systematic research on the growth characteristics and expected benefits of trees in different areas and habitats of the city in terms of their individual formation process, historical reasons, tree species and ecological factors. The investigation on the quantity and quality of significant trees can directly measure the overall status of green space ecology and trees in the region, and its spatial distribution can reflect the ecological level of different urban areas from the side. The in-depth study on them can not only provide an important basis for the selection, management, protection and evaluation of urban garden tree species, but also help to maintain the urban zonal vegetation style and improve the quality of urban green space. Based on the previous team's proposal of the concept of urban significant trees, the construction of the evaluation index system, and the identification of significant trees in the main urban area of the first ring road of Hefei [1], this paper expanded the research scope, further identified the significant trees in Yaohai district and the government district of Hefei, and analyzed the structure, diversity and spatial distribution of significant tree species, with a view to improving the protection, management and scientific maintenance of urban trees, further explore the growth potential of urban trees.

2. Overview of the study area

Hefei is located in the Jianghuai hills, between 31° 38'–31° 58'N and 117° 11'–117° 22'E. The main landform in the territory is mainly hilly land, belonging to subtropical monsoon humid climate, subtropical evergreen broad-leaved forest vegetation zone, with four distinct seasons. The annual average precipitation is about 1000 mm, the annual sunshine is about 2000 h, the annual average temperature is 15.7℃, the annual frost free period is 228 days, and the average relative humidity is 77%. The main vegetation type is coniferous and broad-leaved mixed forest composed of evergreen forest and deciduous forest.

The scope of this study covers the main urban area of the first ring road, yaohai district and government affairs District of Hefei. The main urban area of the first ring road is within the first ring road of Hefei, with a survey area of 16 km^2; the green space pattern in this area is based on the old city wall of the old city of Hefei, with about 137.6 hm^2 of urban park around the city as the core. It has a good ecological background, a stable ecological environment and a high degree of naturalization. Yaohai District, which is adjacent to the main urban area of the first ring road, is located in the east of Yaohai District, covering an area of 64.4 km^2. It is an industrial oriented urban functional area. The sample plots in this area are Changhuai, shengli Road, sanli street, tongling Road and Mingguang Road, with a total area of 12.83 km^2. The administrative area is located in the southwest of the main urban area, with a survey area of 12.67 km^2. As the political and economic center and commercial and cultural center of Hefei, its greening construction scale and indicators rank first in all districts of Hefei. The field survey time of the salient trees in the study area varies according to the regional distribution. The survey time in the main urban area of the first ring road is from April 2016 to March 2017, and that in Yaohai district and

government district is from September 2017 to March 2020.

3. Research methods

3.1. Recognition standard of significant tree

According to the evaluation index system [1] built by the team for urban prominent trees in the early stage, the urban trees to be evaluated in the study area are evaluated by 6 qualitative indicators and 12 quantitative indicators, of which 6 qualitative indicators are B1 historical witness (C1 historical witness, c2 historical logo, c3 historical culture), b2 social culture (C4 memorial significance, c5 allusions, c6 nostalgia); the 12 quantitative indicators are B3 tree age and vitality (C7 tree age, c8 growth, c9 pest status), b4 volume (C10 DBH, c11 tree height, c12 crown width), b5 tree species (C13 rarity, c14 germplasm resources), b6 site location (C15 visual contribution, c16 site location), b7 aesthetic value (C17 tree shape beauty, c18 color beauty). If it meets the conditions of qualitative indicators, it can be recognized as a significant tree. If the quantitative indicators are given a score of 1–5 points according to the standard conditions, the trees to be evaluated can be recognized as a significant tree if the comprehensive score of quantitative indicators is 30 points or more.

3.2. Significant tree survey method

With reference to the definition of significant trees by the research team, based on field investigation, the trees existing in parks, streets, residential areas, government schools and other places in the study area were surveyed and observed, and the potential trees that may serve as significant trees within the three areas were preliminarily screened. In combination with the site environment and growth status of trees, various index values of trees are measured according to the qualitative and quantitative evaluation index system of urban significant trees, and data such as species name, height, horizontal branch and leaf crown width, standing tree diameter, tree age, potential cultural value attributes are recorded. At the same time, coordinates are positioned, photos are taken to record the growth status of trees, and a sample database of urban potential significant trees is established.

3.2.1. Qualitative index investigation

Qualitative index investigation is to consider the potential cultural value of urban trees. By means of field investigation and literature review, combined with residents' evaluation, and in connection with the growth background and site environment of trees, the historical and cultural value, urban impression and nostalgic plot of urban trees are excavated.

3.2.2. Quantitative index investigation

1) Investigation on tree species, tree age, growth and landscape aesthetic value. Identify the tree species according to the professional knowledge of the investigators. For uncertain tree species, collect their branches, leaves and fruits samples and compare them with books or ask experts for identification; tree age survey mainly adopts interview estimation, document tracking and field survey to estimate; the growth and landscape aesthetics were scored subjectively with reference to quantitative indicators.

2) Investigation on the volume index of DBH, crown width and height of trees. Take the place where the trunk is 1.3 m higher than the ground as the measuring point, measure the maximum and minimum DBH of the trunk with a tape, and then take the average value as the average DBH of the tree; at the same time, measure the longest and shortest width of the growth edge of the tree branches and leaves with a tape according to the tree growth trend, and take the average value as the average crown width of the tree; the height of trees shall be measured at appropriate intervals according to the site environment of trees by using the brules altimeter. At the same time, the auxiliary measurement shall be conducted with reference to the observable structures around the trees.

3.3. Calculation method of relevant indicators

Common species diversity analysis methods are used to analyze the distribution characteristics of significant trees in each region, and the richness index (s) and Pielou evenness index (J) are calculated to reflect the differences in species and distribution of significant trees in cities in different regions; simpson index (d) and Shannon Wiener index (H) are used as indicators to comprehensively reflect or analyze the species diversity in each region; calculate the relative abundance (the number of trees in the species/the total number of trees in the study area) to analyze the characteristics of significant tree species in Hefei.

Table 1. Recognized distribution and scores of urban significant trees.

	Qualitative index/plant		**Quantitative index/point**		
	Historical witness	**Society and culture**	**41–45**	**36–40**	**30–35**
First ring main urban area	18	3	12	27	52
Yaohai District	1	1	2	37	306
Administrative district	0	0	0	6	63
Total	19	4	14	70	421
Percentage/(%)	3.60	0.76	2.65	13.26	79.73

4. Results and analysis

4.1. Evaluation, score and distribution of urban significant trees

In this assessment of the significant trees in Yaohai district and the government affairs District, 859 urban significant trees were nominated and 416 were identified by reference to the evaluation index system. In combination with the previous identification of 112 significant trees in the main urban area of the first ring road by the discipline team, 528 significant trees were identified in the main urban area of the first ring road, yaohai and the government affairs District of Hefei. Among the identified significant trees, 23 were identified by qualitative indicators, accounting for 4.36%; 505 plants were identified by quantitative indexes, accounting for 95.64%; according to the distribution of score values, there are 421 plants with scores ranging from 30 to 35, accounting for 79.73%, 70 plants with scores ranging from 36 to 40, accounting for 13.26%, and only 14 plants with scores ranging from 41 to 45, accounting for 2.65%. The number of significant trees and the distribution of score

values decrease step by step in a pyramid shape (**Table 1**).

In terms of regional distribution, there are 112 significant trees in the main urban area of the first ring road (21 of which are identified by qualitative indicators), 347 trees in Yaohai district (2 of which are identified by qualitative indicators), and 69 trees in the administrative area. According to the history of urban construction and development, the first ring main urban area and Yaohai district were developed and constructed earlier. They are typical old urban areas of Hefei. Therefore, the number of significant trees with historical testimony and social culture is significantly higher than that of the government affairs district. In terms of the distribution of significant trees quantitatively assessed, the main urban area is located in the central area of Hefei, with rapid renewal and development, and relatively dense construction population. In addition to the protection of ancient and famous trees, other trees are also facing the problems of renewal and transformation, and the tight utilization of their habitat resources, resulting in certain restrictions on the growth space of trees. Therefore, the number of significant trees that can achieve the expected growth is far less than that in Yaohai district.

4.2. Composition, relative abundance and structural characteristics of urban prominent trees

4.2.1. Composition and relative abundance of urban significant tree species

In zone 3,528 significant trees were identified, belonging to 27 families, 36 genera and 40 species. According to the relative abundance value of tree species, the top 4 were Platanus acerifolia (26.52%), cinnamommum camphora (14.02%), ginkgo biloba (5.68%) and Cedrus deodara (5.49%). In the early urban landscaping construction of Hefei, in order to meet the requirements of forming a good landscape effect in a short time, two ball sycamore and Cinnamomum camphora were widely used as shade trees in street trees and leisure green space. Practice has also proved that compared with other tree species, platanus acerifolia and Cinnamomum camphora have the advantages of long-term tolerance to adverse environmental factors of habitat, pollution resistance and strong vitality.

The composition and relative abundance of significant tree species in different urban areas are different. According to the development of Hefei City, the trees in the main urban area and Yaohai district mainly originated from the road greening in the 1950s–1960s and the afforestation activities in the 1970s–1980s, while the trees in the government area mostly originated from the urban landscaping construction around 2000, resulting in differences in significant tree species.

Table 2. Distribution of age, life form and local characteristics of urban significant trees.

	Age structure/plant					Life form characteristics (species/plant)				Local characteristics (species/plant)	
	>100	81–100	61–80	41–60	20–40	Evergreen broad leaved	Evergreen needle	Deciduous broad leaf	Deciduous needle	Native tree species	Non native tree species
First ring main urban area	21	3	22	27	39	3/12	4/17	16/83	0	17/69	9/43
Yaohai District	1	13	46	92	195	5/75	1/15	21/234	1/23	18/79	10/268
Administrative district	0	0	6	16	47	3/22	1/8	12/38	1/1	8/23	9/46
Total	22	16	74	135	281	6/109	4/40	28/355	2/24	23/171	17/357
Proportion of plants/(%)	4.16	3.03	14.02	25.57	53.22	20.64	7.58	67.23	4.55	32.39	67.61

4.2.2. Age composition, life style and local structural characteristics

More than half of the significant trees assessed in the three areas are 20–40 years old, and there are 22 trees with a tree age of more than 100 years. As the main urban area has a long history, the number of ancient and famous trees actually surveyed and protected by decree is the largest, so the overall age of significant trees is the highest in the three areas, and the age distribution is the most uniform. In terms of life form, there are 10 evergreen species, 149 in total, and 30 deciduous species, 379 in total. The ratio of evergreen to deciduous species is 1:3, and the ratio of plant number is about 2:5. In addition, there are 6 species of evergreen broad-leaved trees with 109 trees in total, and 4 species of evergreen coniferous trees with 40 trees in total; there are 28 species of deciduous broad-leaved trees, 355 in total, accounting for more than 2/3; there are 2 species of deciduous coniferous trees, with a total of 24 trees. The significant tree life form characteristics in zone 3 are also that the proportion of deciduous tree species is much higher than that of evergreen tree species, and the proportion of broad-leaved tree species is much higher than that of coniferous tree species. In terms of local structural characteristics, among the significant trees in Hefei City, there are 23 native species, accounting for more than half, but the number of trees is only 171, accounting for less than 1/3 (32.39%); in the region, except for the administrative area, the proportion of native trees is higher than that of non-native trees, but the number of plants is dominated by non-native trees except for the first ring main urban area (**Table 2**).

4.3. Height, diameter at breast height, crown area, diversity and site location characteristics of urban significant trees

4.3.1. Characteristics of height, diameter at breast height and crown area of urban significant trees

Through statistical analysis, the average height of significant trees in Hefei is 12.68 m, the average DBH is 0.44 m, and the total crown area is 59,100.14 m^2. In terms of regional distribution, the average tree height in Yaohai district is the largest,

which is 12.84 M. Based on the significant tree number advantage, the total area of crown width is the largest, which is 36,278.31 m^2; the dominant age of significant trees in the main urban area is so obvious that the average DBH reaches 0.58 m, which is significantly higher than that in other areas; affected by the development time, the height, diameter at breast height and crown width of the administrative area are significantly lower than those of the other two areas.

4.3.2. Diversity characteristics of regional significant trees

Through the calculation and analysis of diversity indicators, it can be seen that the main urban area of Hefei has a long history of urban development and the greening construction started early. Its species diversity index, namely Shannon Wiener index and Simpson index, is the highest among the three urban areas, which are 2.77 and 0.93 respectively; as the political, economic and cultural center of Hefei City, the government district belongs to the later construction planning area, which is more scientific and modern in the regional development planning. In the process of landscape construction, the use of plants, especially arbor species, pays more attention to the diversity and comprehensiveness of trees. In terms of the Shannon Wiener and Simpson index values, it is second only to the main urban area, 2.54 and 0.92, while in terms of the species evenness index, it is 0.90, 0.88 higher than that of the main urban area; yaohai District, as an old industrial area in Hefei, has the lowest Shannon Wiener index, simpson index and species evenness index, which are 2.32, 0.82 and 0.69 respectively (**Table 3**).

Table 3. Height, diameter at breast height, crown area and diversity characteristics of urban significant trees.

Region	Average tree height/M	Average DBH/M	Crown area/m^2	Shannon – Wiener index	Simpson index	Pielo index
First ring main urban area	12.56	0.58	14,125.58	2.77	0.93	0.88
Yaohai District	12.84	0.41	36,278.31	2.32	0.82	0.69
Administrative district	12.04	0.34	8696.25	2.54	0.92	0.90
Hefei	12.68	0.44	59,100.14	–	–	–

4.3.3. Location distribution characteristics of urban prominent sites

From the assessment of the growth environment and location of significant trees, hefei has the largest number of significant trees in urban roads, residential areas and parks, with 188, 187 and 91 trees respectively, accounting for 88.26% of the three land types; the number of significant trees in other land types, such as land for government organizations, schools, public facilities, scenic spots and religions, accounted for only 11.74% of the total survey. From the perspective of each region, the location of significant sites in zone 3 is closely related to the development of their respective urban areas and the layout of green space structure: the green space pattern in the main urban area of the first ring road radiates outward from the Central Park, and the site type with the largest number of significant trees is also the park land. The number of significant trees accounts for 63.39% of the total number of significant trees in the region, followed by residential areas and school land, accounting for 11.61% and 8.04%; the roads and residential areas in Yaohai district have small changes in urban development and construction, and the number of significant trees preserved is also mainly

concentrated in such land types. The number of significant trees in road land is 47.26%, and the number of residential land is 39.19%; among the residential, road and park land types in the administrative area, the number of urban significant trees is the largest, and the number of significant trees in the three types of land accounts for 91.30% of the total in the area (**Table 4**).

Table 4. Location distribution characteristics of urban prominent sites.

	First ring main urban area		Yaohai District		Administrative culture new area		Hefei	
	Number of significant trees/ Plant	Regional proportion/ (%)	Number of significant trees/ Plant	Regional proportion/ (%)	Number of significant trees/ Plant	Regional proportion/ (%)	Number of significant trees/ Plant	Total proportion/(%)
Park	71	63.39	10	2.88	10	14.49	91	17.23
Residential land	13	11.61	136	39.19	38	55.07	187	35.42
Road	9	8.04	164	47.26	15	21.74	188	35.61
School	8	7.14	9	2.59	1	1.45	18	3.41
Famous scenery	4	3.57	0	0.00	0	0.00	4	0.76
Organization	3	2.68	20	5.76	3	5.76	26	4.92
Religious land	1	0.89	0	0.00	0	0.00	1	0.19
Land for public equipment	3	2.68	8	2.31	2	2.31	13	2.46

5. Conclusions

The preliminary research area of the team is limited to the main urban area of Hefei first ring road. In this paper, the evaluation indicators are used to supplement the identification of significant trees in the whole area of the five streets and government districts of Yaohai District, expand the research scope, and compare and analyze the tree species structure, diversity and spatial distribution of urban significant trees in various regions of Hefei, so as to build a more favorable growth environment for urban trees in the urban environment and stimulate the biological potential of urban trees, and then more effectively improve the ecological benefits of urban trees. The main conclusions of this study are as follows:

1) In the evaluation of urban significant trees, only 23 significant trees were evaluated by historical witness, social culture and other qualitative indicators, far less than the 505 trees evaluated quantitatively. The cultural value of urban trees still needs to be further explored. The construction and development of urban greening should pay attention to the protection and cultivation of urban tree culture.

2) The number and distribution of urban prominent trees are closely related to the construction history and renewal development of the urban area. The number and distribution of urban prominent trees in the first ring main urban area and Yaohai district are significantly higher than that in the administrative area. The tree species such as sycamore, camphor, gingko and cedar have obvious advantages; in addition, most of the significant tree species are deciduous broad-leaved trees, both evergreen

broad-leaved, coniferous and deciduous coniferous trees, which conform to the characteristics of regional zonal vegetation; foreign fast-growing and adaptive tree species selected for urban early greening construction, after growth and development, account for more of the significant urban trees than native tree species, so they have more advantages.

3) Although the distribution of significant established land types varies in different regions due to the differences in planning, construction and development, their distribution is mainly concentrated in three land types: urban roads, residential areas and parks. In the future, we can study the relationship between significant tree growth and its biological characteristics under different land types, and then formulate significant tree protection policies according to local conditions.

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