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Aromatic Plant Resources and Their Landscape Application in Hefei City

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Abstract Taking Hefei City as the research site, preliminary investigations were conducted into its aromatic plant resources to fill the gap in systematic research and establish a localized database in this study. Based on the analysis and organization of data on Hefei's aromatic plant resources, the Analytic Hierarchy Process (AHP) was employed to quantitatively evaluate their comprehensive value (ecology, landscape, economy, etc.), so as to construct a comprehensive evaluation model for these resources and screen high-value plant species. Finally, based on the above objective investigation and analysis, recommendations were proposed for the landscape application of aromatic plant resources in Hefei, aiming to build an integrated ecological-landscape-economic value system.

Keywords Aromatic plants, Hefei City, Analytic Hierarchy Process, Landscape application
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With the acceleration of urbanization, the value of urban green space systems in ecological services, landscape aesthetics and public health has become increasingly prominent. Aromatic plants, owing to their unique olfactory experiences and multidimensional functions, have gradually emerged as critical elements in urban landscaping[1]. Hefei City, situated in the Jianghuai hilly region with a humid climate and abundant plant resources, hosts characteristic aromatic plants such as *Osmanthus fragrans* and *Gardenia jasminoides*, which exhibit both ecological adaptability and cultural significance[2]. However, current utilization of aromatic plant resources in Hefei faces challenges including uneven species distribution, limited application scenarios, and underutilized comprehensive value. It is urgent to construct a scientific evaluation system to guide its optimal allocation.

In recent years, domestic and international scholars have conducted multidimensional research on the landscape application of aromatic plants. Ecologically, studies demonstrate that aromatic plants improve air quality by releasing volatile organic compounds (VOCs)[3]. Therapeutically, fragrances from plants like *Lavandula* have been shown to alleviate anxiety[4]. However, existing research predominantly focuses on single-function evaluations, lacking systematic quantitative analysis of the comprehensive ecological-landscape-economic value of plant resources. Therefore, constructing a comprehensive evaluation system of aromatic plant resources in Hefei City and screening high-value plant species is not only an innovative breakthrough in academic research, but also a key path to synergize multiple objectives including ecological livability, economic sustainability and cultural prominence and make Hefei an "olfactory landscape city" with national demonstration significance.

1 General situation of the research area

Hefei City, the capital of Anhui Province (31°52' N, 117°17' E), is located in central Anhui and the western wing of the Yangtze River Delta. It lies in the northern subtropical humid monsoon climate zone, characterized by mild temperatures, distinct seasons, an annual average temperature of 15–16 °C, and annual precipitation of approximately 1 000 mm. The terrain is dominated by the Jianghuai hilly region, with higher elevations in the northwest and lower in the southeast, averaging 20–50 m above sea level[5]. As a sub-central city in the Yangtze River Delta urban agglomeration, Hefei is also a national garden city and a national forest city. The urban greening is dominated by *Cinnamomum camphora*, *Osmanthus fragrans*, and *Ginkgo biloba*, with a green coverage rate of 45.3%[6].

2 Research methods

2.1 Statistics of aromatic plants

A comprehensive survey of aromatic plants in Hefei City identified 69 species belonging to 57 genera of 28 families (Table 1), covering trees, shrubs, and herbs. These plants are distributed across streets, parks, schools, suburbs, botanical gardens, and flower markets.

2.2 Research methods

The Analytic Hierarchy Process (AHP), proposed by American operations researcher Thomas L. Saaty in the 1970s, is a multi-criteria decision analysis method integrating quantitative and qualitative approaches. It decomposes objectives into multiple sub-goals or criteria, further breaking them into hierarchical levels of indicators (or criteria/constraints), and through fuzzy quantification of qualitative indicators, the hierarchical single ranking (weight) and total ranking are calculated. AHP serves as a systematic method for optimizing decisions involving multiple objectives or solutions[7]. Currently, it is widely applied in resource evaluation and landscape planning as a multi-criteria decision tool[8].

2.3 Construction of comprehensive evaluation model

Due to the excessive species of aromatic plant resources in Hefei City, 20 woody plant species were selected to construct a comprehensive evaluation model in this study. These species were as follows: *O. fragrans*, *Jasminum nudiflorum*, *Syringa oblata*, *Rosa chinensis*, *Rosa rugosa*, *Prunus mume*, *Rosa banksiae*, *Wisteria sinensis*, *Albizia julibrissin*, *Michelia figo*, *Michelia alba*, *Lonicera japonica*, *C. camphora*, *Daphne odora*, *Edgeworthia chrysantha*, *G. jasminoides*, *Rosmarinus officinalis*, *Chimonanthus praecox*, *Citrus medica*, and *Trachelospermum jasminoides*.

Using these 20 aromatic plant species as evaluation objects, the hierarchical structure of the evaluation index system for aromatic plants was established, comprising the objective layer (A), constraint layer (C), index layer (P), and plan layer (D), forming a hierarchical evaluation model (Table 1). Based on a review of relevant

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literature, the comprehensive evaluation of aromatic plants was designated as the objective level (A). The three major factors influencing the value of aromatic plants, ecology (C_1), landscape (C_2), and economy (C_3), were defined as the constraint layer (C). Sixteen evaluation factors, including carbon sequestration capacity and dust retention capacity, were selected as the index layer (P). The plan layer (D) consisted of the 20 aromatic plant species to be evaluated. The pairwise comparison method and the 1−9 scaling method were then applied to construct judgment matrices, calculate the weight (W) values of the indexes, and perform consistency checks on the matrices. Finally, the total ranking weight values were obtained through weighted calculation.

2.4 Determination of index weights

In this evaluation process, three experts in relevant fields and 15 randomly selected individuals of varying ages and genders were invited to conduct pairwise comparisons on the three factors in the constraint layer and the 16 factors in the index layer. Averaged judgment matrices were derived to reduce judgment bias. The 1-9 scaling method was applied to assign values to the relative importance degree. These values were then summarized, averaged, and used to calculate relative weights (W), and four judgment matrices were thereby constructed: A-C, C_1-P, C_2-P, and C_3-P. The final judgment matrix model is presented in Table 2.

Meanwhile, the maximum eigenvalue (λ_{max}) of each judgment matrix was calculated to reduce subjective judgment errors caused by manually assigned scores, and the reliability of the matrices should be checked. When the maximum eigenvalue λmax is closer to 1, that is, when the *CI* value is smaller, the construction is more reasonable. The formula for calculating *CI* is as follows:

$CI=\lambda_{max}-n/n-1$ (*n* is the order of the judgment matrix)

CR, the consistency ratio, is calculated according to $CR=CI/RI$, where *CI* is the consistency index and *RI* is the random index (for n=1−9, the *RI* values are 0.00, 0.58, 0.90, 1.12, 1.24, 1.32, 1.41, and 1.45, respectively). When $CR < 0.10$, the matrix consistency is considered good, and the matrix passes the consistency check. Otherwise, the judgment matrix needs adjustment. As shown in Table 2, the *CR* values of all matrices were below 0.10, meeting the consistency check requirements, indicating reasonable results.

2.5 Comprehensive evaluation of aromatic plants

The 20 surveyed aromatic plants were scientifically scored by referencing authoritative literature[9]. The weights (W_p) of various index factors in the index layer (P) relative to the objective layer (A) through the constraint layer (C) were then calculated, as shown in Table 3.

The Analytic Hierarchy Process (AHP) method was applied to evaluate the comprehensive value of each aromatic plant. The comprehensive evaluation values of aromatic plants in Hefei City were obtained, as shown in Table 4.

3 Conclusions and Discussion

In this study, the Analytic Hierarchy Process

Table 1 Comprehensive evaluation model of aromatic plants

Objective layer (A)	Constraint layer (C)	Index layer (P)	Plan layer (D)
Comprehensive evaluation of aromatic plants (A)	Ecological benefits (C1)	Carbon sequestration capacity (P_1), dust retention capacity (P_2), disease and pest resistance (P_3), drought/waterlogging resistance (P_4), barren tolerance (P_5), pruning tolerance (P_6)	Twenty species of aromatic plants to be evaluated (D_1, D_2, D_3, …, D_{20})
	Landscape value (C2)	Flower color (P_7), flowering period (P_8), aesthetic appearance (P_9), aroma intensity (P_{10}), public acceptance (P_{11}), cultural fit (P_{12})	
	Economic value (C3)	Planting cost (P_{13}), derivative economic value (P_{14}), market demand (P_{15}), breeding difficulty (P_{16})	

Table 2 Constructed judgment matrix and consistency check

Hierarchical model	Judgment matrix							Relative weight (W)	Consistency check
A-C		C_1	C_2	C_3					λ_{max}=3.039 *CI*=0.019 *CR*=0.037<0.1
	C_1 Ecological benefits	1	3	5				0.633	
	C_2 Landscape value	1/3	1	2				0.261	
	C_3 Economic value	1/5	1/3	1				0.106	
C_1-P		P_1	P_2	P_3	P_4	P_5	P_6		λ_{max}=6.419 *CI*=0.084 *CR*=0.067<0.1
	P_1 Carbon sequestration capacity	1	3	5	5	9	7	0.444	
	P_2 Dust retention capacity	1/3	1	3	5	7	5	0.254	
	P_3 Disease and pest resistance	1/5	1/3	1	3	5	1	0.112	
	P_4 Drought/waterlogging resistance	1/5	1/5	1/3	1	3	1/3	0.059	
	P_5 Barren tolerance	1/9	1/7	1/5	1/3	1	1/5	0.028	
	P_6 Pruning tolerance	1/7	1/5	1	3	5	1	0.103	
C_2-P		P_7	P_8	P_9	P_{10}	P_{11}	P_{12}		λ_{max}=6.543 *CI*=0.109 *CR*=0.087<0.1
	P_7 Flower color	1	1/3	7	5	1/5	1/3	0.126	
	P_8 Flowering period	3	1	7	5	1/3	1	0.202	
	P_9 Aesthetic appearance	1/7	1/7	1	1/3	1/7	1/5	0.031	
	P_{10} Aroma intensity	1/5	1/5	3	1	1/5	1/5	0.054	
	P_{11} Public acceptance	5	3	7	5	1	3	0.396	
	P_{12} Cultural fit	3	1	5	5	1/3	1	0.191	
C_3-P		P_{13}	P_{14}	P_{15}	P_{16}				λ_{max}=4.117 *CI*=0.039 *CR*=0.044<0.1
	P_{13} Planting cost	1	1/3	1/5	3			0.122	
	P_{14} Derivative economic value	3	1	1/3	5			0.263	
	P_{15} Market demand	5	3	1	7			0.558	
	P_{16} Breeding difficulty	1/3	1/5	1/7	1			0.057	

Table 3 Weight ranking of index factors

Layer A	Layer C	WC	Layer P	WP	Weight	Ranking
Comprehensive evaluation of aromatic plant	C_1 Ecological benefits	0.633	P_1 Carbon sequestration capacity	0.444	0.281	1
			P_2 Dust retention capacity	0.254	0.160 8	2
			P_3 Pest and disease resistance	0.112	0.070 9	4
			P_4 Drought/Waterlogging tolerance	0.059	0.037 3	9
			P_5 Barren tolerance	0.028	0.017 7	12
			P_6 Pruning tolerance	0.103	0.065 2	5
	C_2 Landscape value	0.261	P_7 Flower color	0.126	0.032 9	10
			P_8 Flowering period	0.202	0.052 7	7
			P_9 Aesthetic appearance	0.031	0.008 1	15
			P_{10} Aroma intensity	0.054	0.014 1	13
			P_{11} Public acceptance	0.396	0.103 4	3
			P_{12} Cultural fit	0.191	0.049 9	8
	C_3 Economic value	0.106	P_{13} Planting cost	0.122	0.012 9	14
			P_{14} Derivative economic value	0.263	0.027 9	11
			P_{15} Market demand	0.558	0.059 1	6
			P_{16} Breeding difficulty	0.057	0.006 0	16

Table 4 Comprehensive evaluation values of aromatic plants

Plant name	Evaluation value	Evaluation grade	Plant name	Evaluation value	Evaluation grade
C. camphora	2.639	I	*G. jasminoides*	2.218	II
O. fragrans	2.575		*A. julibrissin*	2.172	
R. chinensis	2.399	III	*T. jasminoides*	2.071	
L. japonica	2.392		*Michelia × alba*	2.055	
Armeniaca mume	2.367		*E. chrysantha*	2.051	
Wisteria chinensis	2.314		*Eugenia caryophyllata*	2.047	
R. rugosa	2.311		*D. odora*	2.039	
R. banksiae	2.310		*M. figo*	2.012	
Chimonanthus praecox	2.283		*C. medica*	2.000	
Jasminum nudiflorum	2.279		*Salvia rosmarinus*	1.735	III

(AHP) method was applied to establish a comprehensive value evaluation index system for aromatic plants applied in landscaping in Hefei City. Among the total ranking weights of the constraint layer (C) relative to the objective layer (A), ecological benefits (C_1) exerted the strongest constraining force on the objective layer. In the ranking weights of the criterion layer (P) relative to the objective layer (A), carbon sequestration capacity, dust retention capacity, and public acceptance showed the highest weights, contributing most significantly to the comprehensive value evaluation of aromatic plants. Future value evaluation of aromatic plants should focus on these aspects to guide their practical application in landscaping.

Based on the Analytic Hierarchy Process (AHP) and the 3-point scoring system, aromatic plants in Hefei City were classified into three categories according to their comprehensive scores: grade I ($L \geqslant 2.5$) with high comprehensive application value, grade II ($2.0 \leqslant L < 2.5$) with moderate comprehensive application value, and grade III ($L < 2.0$) with low comprehensive application value. As shown in Table 4, the two tree species with high recommendation coefficients were classified as grade I, both being arbor species. Eleven species with moderate recommendation coefficients were categorized as grade II, including 4 arbor species, 9 shrub species, and 4 vine species. One species with a low comprehensive recommendation coefficient was classified as grade III, belonging to the shrub category.

C. camphora and *O. fragrans* of grade I with high recommendation coefficients, as core species in Hefei's urban landscaping, exhibit strong ecological benefits with exceptional dust retention and carbon sequestration capabilities. *C. camphora*, a common street tree, adapts well to Hefei's complex site conditions, while the *O. fragrans* serves as a vital ecological and landscape element in autumn. Meanwhile, *O. fragrans*, designated as the city flower, and the century-old *C. camphora*, carry urban historical memories, establishing them as dual-core plants in both ecology and culture. The grade II plants, though moderate in comprehensive application value and mostly shrubs or vines, can perform outstandingly in specific scenarios. For example, *L. japonica* and *T. jasminoides* enhance dust retention efficiency through vertical greening, and *R. chinensis* and *R. rugosa* offer high derived economic value through rose essential oil production. *L. japonica* maintains stable demand as a traditional Chinese medicine. *W. chinensis* and *R. banksiae* create multidimensional landscapes via vine coverage, achieving functional diversity and scenario adaptability. The grade III plants, such as *R. officinalis*, have limited landscaping applications due to their small size but possess unique value. As emerging aromatic herbs, they hold potential for developing essential oils, spices, and culinary derivatives, warranting further exploration.

To systematically quantify the ecological, landscape, and economic integrated value of aromatic plant resources in landscaping applications, ecological functions can be optimized by using *C. camphora* trees as the core of the arbor layer and combining it with vines such as *W. chinensis* and *T. jasminoides* to construct a three-dimensional carbon sequestration system. In landscape design, emphasis should be placed on olfactory landscape design, as aromatic plants offer diverse healthcare benefits, including calming the mind, relieving stress, enhancing memory, relieving fatigue, and repelling mosquitoes and flies[10]. Therapeutic gardens can be developed to utilize fragrance for emotional soothing. Economically,

(To be continued in P57)

tourism service talents play an important role in improving the core competitiveness of the scenic area. In the early stage of the development of scenic spots, tangible services such as infrastructure can certainly improve the competitiveness of scenic spots, but in the middle and late stage of the development of scenic spots, improving the intangible service quality of scenic spots can attract more tourists and enhance the influence of scenic spots.

4.5.2 Providing professional training for service personnel. Regular training should be carried out to the scenic area service personnel, including service skills, service attitude, industry knowledge and communication skills[7]. For example, a two-month study to Sheraton Jinan Hotel can be arranged for the staff of the catering business center, covering reception, service awareness, service process and service standards. Relevant teaching materials and cases should be provided to help employees deeply understand and master relevant knowledge and skills. The service personnel themselves should apply the service theory they have learned to the service practice. At the same time, they should master some emergency handling skills on the basis of learning theoretical knowledge. The service personnel team should timely find the problems in the service process and report them to the superiors, and finally put forward targeted suggestions through decision-making. For example, the uniform problem can be easily addressed by wearing eye-catching clothes, which can make it easy for tourists to find the service personnel. In addition, as for the problems strongly complained by the tourists, such as the lack of professional personnel, service personnel should be timely arranged to cooperate with the guide map to provide corresponding guidance services for tourists. These measures can improve the service quality of service personnel in Tianyi Lake scenic area and enhance tourist satisfaction[8].

5 Conclusion

As a tourist attraction with natural beauty, Tai'an Tianyi Lake scenic area has great development potential and ability to attract tourists. However, there are still some deficiencies in service quality, facility construction, environmental health management and professional ability of service personnel, which directly affect the experience and satisfaction of tourists. The implementation of targeted improvement measures and strategic adjustments can improve its service quality and enhance the tourist experience, so as to promote the long-term development and brand building of the scenic area, thereby becoming a more popular tourist attraction for tourists and making greater contributions to the development of regional economy.

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transitioning from resources to industries by converting aromatic plants into material industrial resources such as essential oils, herbal medicines and floral teas, can maximize their value.

Looking into the future, the scientific development of aromatic plant resources in Hefei City can promote eco-city development and achieve the "dual-carbon" goals. Future research should further explore strategies to establish Hefei as an "olfactory landscape city" with the coordinated development of "ecology, economy and culture" in the Yangtze River Delta through multidisciplinary collaboration and global planning.

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