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Full Length Article

Evaluation of New Naturalistic Herb Community Landscape in Shanghai, Hangzhou and Suzhou, China

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Abstract

With the acceleration of urbanization, the urban natural environment has been destroyed and urban native vegetation and spontaneous vegetation has decreased, resulting in the reduction of urban plant diversity. Starting from the landscape design of urban herb communities, this paper elaborates the new naturalistic herb landscape design concept. Through the investigation of the herb community landscape in Shanghai, Hangzhou and Suzhou, herbs belonging to 38 families and 88 species were collected in total and the plant community structure, plant diversity and species composition were analyzed. Moreover, the Delphi method and Analytic Hierarchy Process (AHP) were used to construct a new naturalistic herb community landscape evaluation index system, and the evaluation index system was applied to the evaluation of the survey sampling points. The evaluation results indicated that the scores of herb community landscape in Shanghai, Hangzhou and Suzhou were between 0.32 and 0.65 and the evaluation grades were concentrated in grade II, grade III and grade IV. The evaluation results are consistent with the actual situation. © 2020 Friends Science Publishers

Keywords: Evaluation system; Herb community landscape; New naturalistic design concept; Plant diversity

Introduction

Cities are the focus of the interaction between urbanization and nature. Urbanization has changed the ecological characteristics of urban landscapes. Humans have implemented large-scale renovations of urban land to meet their own needs, which has greatly damaged the urban natural environment and ecosystem, and thus, changed the original vegetation of the city (Ikin *et al.* 2018). In an increasingly crowded urban environment, in addition to water and air, plants have become the only way in which humans interact with nature. Therefore, how to create a plant community landscape that has good ecological functions derived from nature and a higher hierarchy in a barren urban soil environment has become a new problem faced by current landscape designers in plant design.

For a long time, the important role of herbs has been neglected in our urban plant designs. Currently, the combination of decorative shrubs and herbaceous plant communities, planting with a few sporadic trees, is becoming a new trend in global plant landscape design. The herbaceous community landscape is an important part of the urban green space, in many forms. Appeared in our common urban landscapes, such as lawns, flower fields, undergrowth, roof gardens. Herbaceous plant communities can regulate temperature, increase humidity, absorb carbon dioxide and release oxygen and other ecological functions. Its composition and structure have important environmental protection significance in improving local microclimate conditions, protecting biodiversity, filtering pollutants, preventing soil erosion, and reducing greenhouse gas emissions (Wang *et al.* 2016). Alternatively, herbs have developed underground roots, which have effective water holding and anti-erosion abilities. The transpiration of their leaves is also weaker than that of trees, and herb plant layers can be tightly covered on the surface, thus reducing water loss (Siqueira *et al.* 2017). Maintaining soil moisture is particularly important for urban environments that are heavily affected by the heat island effect. In addition, herbs have a shorter growth cycle than trees and shrubs and are much higher in species richness than trees and shrubs.

The new naturalistic design concept is a community-based planting design method that combines herbs in a naturalized form to form an organic and stable community based on the principles of ecology. Using the herbal characteristics of rich species, flexible mixed planting and effective multi-season viewing of flowers and foliage, a plant landscape based on naturalistic planting aesthetics can be designed, and the establishment and expression of community diversity are further emphasized (Smith *et al.* 2015). This concept advocates the application of mixed seeding and blending techniques, emphasizes functional design and utilizes natural workmanship to solve the disadvantages of high cost and the lack of biodiversity in

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traditional urban plant landscape construction and render a landscape design that originates from nature but is elevated to a higher level than nature (Nagase and Dunnett 2013). It emphasizes that the competition trend can be controlled to reduce which is dominated by a few species in the plant community created, through the interspecific competition among natural plants to promote the formation of plant communities and create visual and morphological structural diversity (Smith *et al.* 2006a). Using this theory can create a long flowering, complex plant community that is more attractive to ordinary people (compared to those who have professional ecological knowledge), as well as native invertebrates and other wildlife. For eutrophic and barren soil in urban environments, it is strongly adaptable. More vigorously growing plant communities can capture and retain more soil nutrients, support richer and more diverse animal communities and also limit the ability of invasive species to mature. Rich and complex plant communities can provide effective channels for species migration (Smith *et al.* 2006b). Through these conditions to creates a dynamic plant design rather than a constant one. The rational use of native and non-native plants is emphasized in this plant design to build a stable, complex, and easily managed plant community that simultaneously enhances biodiversity and sustainability.

Currently, the evaluation of the plant community landscape is primarily concentrated in the more complex landscape units in the urban green land system. These landscape units often have a complete plant hierarchy (including tree, shrub and herb layers). Some of these evaluation systems are evaluated from qualitative descriptions; some are evaluated from quantitative descriptions and others are combined for evaluation. The evaluation of the plant community landscape cannot be considered only from the perspective of plant communities themselves but also require consideration of the individual plants in the plant communities and the overall environment around them. Plant communities are the basic units in urban landscape, and various plants are combined to form plant communities. In the research of a plant community landscape evaluation, many scholars have conducted large quantities of work, ranging from simple descriptive evaluations of plant physiological and biological characteristics to the comprehensive evaluation of plant communities, such as the landscape aesthetic evaluation, ecological benefit and social value evaluations. Research on the quantitative evaluation of the plant landscape has become a trend in development (Wei and Chen 2015; Yang *et al.* 2015; Chen *et al.* 2016; Duan *et al.* 2018; Shi and Tang 2018; Wang *et al.* 2018). However, currently there are still few studies on the evaluation of herb community landscapes. Plant Community Landscape evaluation methods used at this stage does not apply to the evaluation community landscape of herbs, so it will lead to the evaluation of the herb community too one-sided. It is necessary to re-establish a new evaluation system to evaluate the new naturalistic herb community landscape. This paper analyzes and summarizes previous research results and combines the new naturalistic design concept to construct a comprehensive evaluation method of herb community landscape based on the analytic hierarchy process (AHP).

Factors, such as whether the design method is scientific, whether the configuration of the plant community structure is reasonable and whether the selection of plant varieties is appropriate, will directly affect the protection of urban plant diversity, the stability of the urban green space landscape and the ecological benefits of plant communities (Han 2014). Under this premise, based on the principle of scientific rationality, a new naturalistic herb community landscape evaluation system can be constructed to better guide the design of the new naturalistic herb community landscape.

Our research goals included to: (1) Determine whether the structure of existing herb communities and the selection and configuration of plant species are appropriate. (2) Judge whether the plant community has stability or not, whether it can support the protection and development of urban biodiversity and whether the plant landscape is designed for both humans and the animals living in the city. (3) Decide whether the herb community has an effective natural landscape aesthetic and whether the landscape effect can be derived from nature and be elevated to a higher level than nature.

Materials and Methods

Study areas

The three cities of Shanghai, Hangzhou and Suzhou are located in the eastern region of China. Shanghai is located at the confluence of the Yangtze River and the Huangpu River, which is one part of the Yangtze River Delta impact plain, with flat terrain and a high degree of urban modernization. Hangzhou is located in the Yangtze River Delta and Qiantang River basins. The urban terrain is complicated, and the city center is built around the West Lake, which has abundant green landscape. Suzhou is located on the shores of Taihu Lake and belongs to the Taihu plain area. The terrain of the city is flat (Zeng *et al.* 2014; Xie *et al.* 2015; Gou *et al.* 2019). These three cities belong to the Eastern region of China in terms of the flora. Thus, there is no obvious difference in the use of herbs.

The 13 sample plots surveyed in this study are distributed in Shanghai, Hangzhou and Suzhou. There are certain differences in the types and sizes of green areas in these 13 sample plots.

Shanghai, Hangzhou and Suzhou all belong to the subtropical monsoon climate, with four distinct seasons, sufficient sunshine and abundant rainwater. Shanghai has a mild and humid climate with a short spring and autumn and a long winter and summer. In 2013, the city's average temperature was 17.6°C; the sunshine was 1,885.9 h per annum and the precipitation was 1,173.4 mm per annum. More than 60% of the annual rainfall was concentrated in the flood season from May to September. The annual average temperature in Hangzhou is 17.8°C; the average relative humidity is 70.3%; the annual precipitation is 1,454 mm and the annual sunshine hours are 1,765 h. The summer climate is hot and humid. In contrast, the winter is cold and dry and the weather is pleasant in the spring and autumn. The average annual precipitation in Suzhou is 1,100 mm; the annual average temperature is 15.7°C; the average temperature in January is 2.5°C and the average temperature in July is 28°C.

Sampling design

In the "Standard of Urban Green Space Classification" (CJJ/T85-2017), urban green space is divided in to five categories, including park green space (G1), production green space (G2), protective green space (G3), attached green space (G4) and other green space (G5), as well as nine medium classes and 19 sub-classes. Based on the current situation of herb community landscape research, this study selected park green space (G1) as the research object and chose plant communities with relatively intact overall community landscapes, abundant species and good landscape experience. Thus, in the urban areas of Shanghai, Hangzhou and Suzhou, the method of vegetation ecology of Braun-Blanquet approach was adopted to set up the typical plot.

The final 13 green spaces chosen for this study included the Shanghai Chen Shan Botanical Garden, Shanghai World Expo Park, Shanghai Houtan Park, Shanghai Century Park, Shanghai Century Avenue, Hangzhou Huagang Guanyu Park, Hangzhou Botanical Garden, Hangzhou Taiziwan Park, Suzhou Dongyuan Park, Suzhou Baitang Ecological Botanical Park, Suzhou Songtao Street, Suzhou Xi'an Jiaotong-Liverpool University Entrance and roadside Suzhou Renmin Road. The surveys were performed primarily from July to October of 2017 and 2018 when the plants had good growth conditions. In Suzhou, Shanghai and Hangzhou, a total of 13 sample plots were selected, among which one or two sampling points were selected within each sample plot, and a total of 17 sampling points were obtained (Table 1). Using the field plant research method in the vegetation ecological theory, three quadrates were randomly established in each sampling point, and the size of each quadrate used to perform the sampling was 1 m×1 m.

Data collection and measurement

Based on the characteristics of the different plant communities in the survey, for the plant communities with serious human disturbances and plaque inhomogeneous distribution, the names, number of strains/clusters, height, vegetation coverage, and growth status of the herbs and record whether they were wild. The Braun-Blanquet multiple coverage estimation method (Table 2) was applied to estimate the coverage of plants in the herb layers. However, the plant communities with lighter human disturbance activities were measured using a self-made herb coverage measurement frame to record the names, number of strains/clusters, height, vegetation coverage and growth status of herbs, and whether they were wild. To examine the detailed survey methods of plants, the survey manual of the US URORE model was utilized (Zhao *et al*. 2009). The species name for each herb in the quadrate was recorded; the number of trees and the average height were measured, and the coverage was estimated. The species names of the herbs were determined using the Flora of China, Higher Plants of China and the local flora.

Method for sampling of photographic was used in this survey and stipulated that eight photos were taken for each sampling points, including two photos of the sampling point panorama and two photos for each quadrate. When taking a panoramic view of the sampling points, the view was taken twice at a distance of approximately 20 m from the sampling points to include the entire appearance of the community. When taking photos of the quadrates, it was imperative to ensure that all the species in the quadrates were clearly visible. Takeing as many photos as possible on sunny days between 8:00-16:00 to avoid the excessive shadows caused by insufficient light and the height of the person parallel to the ground can always be used to keep the lens direction perpendicular to the person and to maintain a certain depth of field. Photographing non-landscape factors, such as people, vehicles and equipment, should be avoided as much as possible to not affect the observer's evaluation of the landscape (Pan 2012). The information collected from each sampling points is summarized and analyzed to obtain basic information such as plant species, plant community structure and plant community composition, *etc.* (Table 3). Some photos of the sampling points are presented in Fig. 1.

Establishment of an index system

The evaluation system of the new naturalistic planting communities was constructed to provide theoretical guidance for the design, application and practice of the new naturalistic herb community landscape. In this study, the goals were to construct a new naturalistic herb community landscape from the perspectives of the multidisciplinary integration of ecology, aesthetics, horticulture, coenology, and landscape design; a set of systematic, hierarchical and effective comprehensive evaluation index system was established using the combination of quantitative and qualitative analytical methods (Li *et al.* 2018).

The evaluation index of the new naturalistic herb community landscape considered from the aspects of whether the plant community has appropriate ecological features and sustainability, whether there is

Table 1: Survey plot statistics

No.	Name of sample plot	Type of sample plot	Numbers of sampling points
A	Shanghai Chen Shan Botanical Garden	botanical garden	2
B	Shanghai World Expo Park Park	riverside park	2
C	Shanghai Houtan Park	riverside park	1
D	Shanghai Century Park	comprehensive park	1
E	Shanghai Century Avenue	roadside green space	1
F	Hangzhou Huagang Guanyu Park	lakeshore park	1
G	Hangzhou Botanical Garden	botanical garden	2
H	Hangzhou Taiziwan park	comprehensive park	1
I	Suzhou Dongyuan Park	riverside park	1
J	Suzhou Baitang Ecological Botanical Garden	botanical garden	2
K	Suzhou Songtao Street	roadside green space	1
L	Suzhou Xi'an Jiaotong-Liverpool University	campus greenland	1
M	Suzhou Renmin Road	roadside green space	1

Table 2: Braun-Blanquet multiple coverage estimation method

Grade	Fidelity level	Coverage	Mean
5	Abundant	76%-100%	87.5%
4	Normal	51%-75%	62.5%
3	Common	26%-50%	37.5%
2	Occasional	6%-25%	15%
1	Rare	1%-5%	2.5%
+	Very rare	<1%	0.1%
R	Single	Few individuals	

Table 3: Survey sampling points statistics and basic information

Serial number	Name of sampling points	Plant communities	The most important species and important value
A1	Shanghai Chen Shan Botanical Garden 1	*Angelonia angustifolia* + *Salvia leucantha*	*Angelonia angustifolia* 0.6947
A2	Shanghai Chen Shan Botanical Garden 2	*Miscanthus sinensis, Kleine silberspinne*+*Verbena officinalis*	*Miscanthus sinensis, Kleine silberspinne* 0.7102
B1	Shanghai World Expo Park 1	*Pennisetum alopecuroides* cv. 'Little Bunny'+*Gaillardia aristata Pursh.*	*Pennisetum alopecuroides* cv. 'Little Bunny' 0.6991
B2	Shanghai World Expo Park 2	*Spiraea hypericifolia* + *Coreopsis drummondii*	*Spiraea hypericifolia* L. 0.7716
C	Shanghai Houtan Park	*Typha orientalis* + *Bothriochloa ischaemum*	*Typha orientalis* 0.4705
D	Shanghai Century Park	*Echinacea purpurea* + *Monarda didyma*	*Echinacea purpurea* 0.6666
E	Shanghai Century Avenue	*Penstemon campanulatus* + *Verbena bonariensis*	*Penstemon campanulatus* 0.7818
F	Hangzhou Huagang Guanyu Park	*Dendranthema morifolium* + *Plectranthus scutellarioides*	*Dendranthema morifolium* 0.7012
G1	Hangzhou Botanical Garden 1	*Zinnia elegans* + *Curcuma alismatifolia Gagnep.*	*Zinnia elegans* 0.6645
G2	Hangzhou Botanical Garden 2	*Plectranthus scutellarioides* + *Pentas lanceolata*	*Plectranthus scutellarioides* 0.7330
H	Hangzhou Taiziwan park	*Gomphrena globosa* L.+*Symphyotrichum novi-belgii* (L.) *G.L. Nesom*	*Gomphrena globosa* L. 0.5506
I	Suzhou Dongyuan Park	*Spiraea hypericifolia* + *Gomphrena globosa*	*Spiraea hypericifolia* 0.5913
J1	Suzhou Baitang Ecological Botanical Garden 1	*Cosmos sulphureus* Cav. + *Bougainvillea spectabilis* Willd.	*Cosmos sulphureus* Cav. 0.7509
J2	Suzhou Baitang Ecological Botanical Garden 2	*Digitalis purpurea* + *Cytisus scoparius*	*Digitalis purpurea* 0.6982
K	Suzhou Songtao Street	*Dendranthema morifolium* + *Angelonia angustifolia*	*Dendranthema morifolium* 0.6894
L	Suzhou Xi'an Jiaotong-Liverpool University	*Verbena bonariensis* + *Nassella tenuissima*	*Verbena bonariensis* 0.6493
M	Suzhou Renmin Road	*Oenothera speciosa* + *Panicum virgatum*	*Oenothera speciose* 0.5971

an appropriate plant community landscape aesthetic effect and the social value of the plant community. Therefore, the new naturalistic herb community landscape evaluation index system can comprehensively evaluate the species diversity and landscape aesthetic effects of the new naturalistic herb community landscape and guide its design and construction and provide a scientific basis for the selection and configuration of plant varieties and the methods of maintenance and management in the latter period.

In this evaluation, firstly, based on the existing research materials and literature on plant community evaluation, combined with the requirements of the new naturalistic herb landscape design concept, the ecological features and sustainability, landscape aesthetics and social economy are determined as the objective layers of the indices system, from the three aspects of environmental features, individual plant characteristics and plant community landscape, the indices that meet the requirements of this new naturalistic perennial herb community landscape evaluation are summarized as much as possible. Secondly, the Delphi method is used to screen the preliminary evaluation index system, and the all indices that have been collected are subdivided into 8 secondary indices as criteria layer, include plant diversity, plant community vitality, degree of interference, plant community

Fig. 1: Partial photographs of survey sampling points

structure, elements of plant community landscape, elements of plant community configuration, investment and maintenance, and social value. Moreover, based on the 8 secondary indices the indices formed by the elementary and secondary selection are supplemented and improved with reference to the opinions of the experts. 18 third grade indices were obtained as index layer and included the regional characteristics of plant communities, Simpson index of plant species, Shannon-Wiener index of plant species, Pielou uniformity index of plant species, native plant species, ability to provide food for animals in plant communities, human activities, natural disasters, plant community planting design rationality, plant community level, plant communities in coordination with environment, seasonal variation richness, ornamental plants richness, richness of plant life-form structure, indicators for plant growth, construction cost per unit area, maintenance and management cost per unit area, and closeness with humans (Hai *et al.* 2012; Hitchmough and Wagner 2013). Finally, the evaluation index system was established (Table 4).

Value-determined standard of the index system

Among the 18 evaluation indices, the quantitative research indices included the Simpson index of plant species, Shannon-Wiener index of plant species, Pielou uniformity index of plant species. The qualitative research indices included the native plant species, ability to provide food for animals in plant communities, human activities, natural disasters, Plant community level, plant community planting design rationality, richness of ornamental characteristics, seasonal variation richness, coordination of plant communities and the overall environment, richness of plant life-form, plant growth potential, construction cost per unit area, maintenance and management cost per unit area and closeness with humans. In addition, for the evaluation indices that are difficult to quantify, the evaluation is performed by experts to determine a score based on the information in Table 5 and 6. Based on the documentations, statistics data, planar graph materials and photos that can be collected during the survey process, according to the standard values of each evaluation index, the evaluation results of each expert are collected, and the weighted average is obtained to obtain the standard value of each qualitative evaluation index.

Data processing of evaluation index

The indices of the index layer in the new naturalistic herb community landscape evaluation index system constructed in this study reflect the characteristics of plant communities from different aspects. However, when performing the comprehensive evaluation in the following sections, the index cannot be compared because the standard of the score is not uniform. To ensure that the comprehensive evaluation index of the new naturalistic herb community landscape is comparable and differentiated, the Likert Scale was used to quantify qualitative indices, and the values in the interval [0, 1] were used for scoring. The quantitative indices were first calculated and then were standardized processed to a value in the interval [0, 1]. The calculation method of quantitative indices was as follows:

(1) Species relative coverage

Relative coverage

$$C_i = \frac{N_i}{N_0} \times 100\%$$

Where C_i is the relative coverage; N_i is the coverage sum of a particular species in the survey, and N_0 is the total coverage of all species in the quadrat.

(2) Species richness index

Patrick index

$$R = S$$

Where R is the Patrick index of the quadrat and S is the total number of species in the quadrat.

(3) Species important value

Herbal important value:

$$S_i = \frac{(F_i + C_i)}{2}$$

Where C_i = the coverage area of a species / the total coverage area of the same life form plant × 100%, and F_i = the frequency of a certain species / the total frequency of the same life form plants × 100%; where S_i is the species important value; C_i is the relative coverage of species i, and F_i is the relative frequency of species i.

(4) Simpson diversity index

$$D = 1 - \sum_{i=1}^{s} (C_i)^2$$

Where S is the number of plant species in the plant community and C_i is the percentage of the ith plant species coverage in the total coverage of the plant community.

Table 4: New naturalistic herb community landscape evaluation system

New naturalistic herb community landscape evaluation	Objective layer A	Criteria layer B	Index layer C
	Ecological features and Sustainability (A1)	Plant diversity (B1)	Regional characteristics of plant communities (C1)
			Simpson index of plant species (C2)
			Shannon-Wiener index of plant species (C3)
			Pielou uniformity index of plant species (C4)
		Plant community vitality (B2)	Spontaneous plant species (C5)
			Ability to provide food for animals in plant communities (C6)
		Degree of interference (B3)	Human activities (such as pruning, removing litter, replanting and picking flowers, leaves, fruits and branches) (C7)
			Natural disasters (such as diseases and insect pests, wind disasters and fires) (C8)
	Landscape aesthetics feature (A2)	Plant community structure (B4)	Plant community planting design rationality (C9)
			Plant community level (C10)
			Plant communities in coordination with environment (C11)
		Elements of plant community landscape (B5)	Seasonal variation richness (C12)
			Ornamental plants richness (C13)
		Elements of plant community configuration (B6)	Richness of plant life-form structure(C14)
			Indicators for plant growth (C15)
	Social economy feature (A3)	Investment and Maintenance (B7)	Construction cost per unit area (C16)
			Maintenance and management cost per unit area (C17)
		Social value (B8)	Closeness with humans (C18)

Table 5: Expert score sheet

Project New naturalistic herb community evaluation	Objective layer A	Index layer C	Scores 0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1
	Ecological features and Sustainability (A1)	Regional characteristics of plant communities (C1)					
		Simpson index of plant species (C2)					
		Shannon-Wiener index of plant species (C3)					
		Pielou uniformity index of plant species (C4)					
		Spontaneous plant species (C5)					
		Ability to provide food for animals in plant communities (C6)					
		Human activities (such as pruning, removing litter, replanting, and picking flowers, leaves, fruits and branches) (C7)					
		Natural disasters (such as diseases and insect pests, wind disasters and fires) (C8)					
	Landscape aesthetics feature (A2)	Plant community planting design rationality (C9)					
		Plant community level (C10)					
		Plant communities in Coordination with environment (C11)					
		Seasonal variation richness (C12)					
		Ornamental plants richness (C13)					
		Richness of plant life-form structure(C14)					
		Indicators for plant growth (C15)					
	Social economy feature (A3)	Construction cost per unit area (C16)					
		Maintenance and management cost per unit area (C17)					
		Closeness with humans (C18)					

(5) Shannon-Wiener diversity index

$$H = -\sum_{i=1}^{s} C_i \ln C_i$$

Where H is the Shannon-Wiener diversity index; C_i is the proportion of the total coverage of species i in all quadrats to the total coverage of all species in all quadrats, and S is the number of total species.

(6) Species evenness index

Pielou evenness index:

$$E = \frac{H}{\ln S}$$

Where E is the Pielou evenness index; H is the Shannon-Wiener diversity index and S is the total number of species.

Calculation of evaluation index weights

Based on the synthesis of previous research, as well as the processing and analysis of the survey data collected, the analytic hierarchy process was utilized to obtain the weights of all the indices of the new naturalistic herb community landscape evaluation index system. The Analytical Hierarchy Process (AHP) is a method of hierarchical weighted decision analysis proposed by the American operations researcher T. L. Saaty in the mid-1970s. This is a multi-objective decision-making method that combines quantitative and qualitative analyses and it is a scientific and complete evaluation system (Woźniak *et al.* 2018).

(1) We determined the target and evaluation factor set u and constructed a hierarchical structure model. At this point, u was the new naturalistic herb community indicator system constructed (Table 4). (2) We constructed an interpretation matrix. For the target, u_i represented the evaluation factor, if $u_i \in u(i = 1, 2, 3, \ldots, n)$; u_{ij} represented

Table 6: The standard value of each index

Plant diversity (B1)	Regional characteristics of plant communities (C1)	The regional characteristics of the plant communities are very obvious, and more than 80% of the plant species are native plants. ——1 The regional characteristics of the plant communities are obvious, and 60%-79% of the plant species are native plants. ——0.8 The regional characteristics of the plant communities are relatively obvious, and 50%-79% of the plant species are native plants. ——0.6 The regional characteristics of the plant communities are ordinary, and 20%-39% of the plant species are native plants. ——0.4 There are no regional characteristics in the plant communities, and less than 20% of the plant species are native plants. ——0.2
	Simpson index of plant species (C2) Shannon-Wiener index of plant species (C3) Pielou uniformity index of plant species (C4)	The original data of simpson index, Shannon-Wiener index, Pielou uniformity index were standardized processed by the method . $X'_{ij} = \frac{X_{ij} - X_{j\min}}{X_{j\max} - X_{j\min}}$ X'_{ij} is the value of the j^{th} index of the i^{th} plant community which was standardized processed; X_{ij} is the original value of the j^{th} index of the i^{th} plant community; $X_{j\min}$ is the minimum value of the j^{th} index, and $X_{j\max}$ is the maximum value of the j^{th} index,
Plant community vitality (B2)	Spontaneous plant species (C5)	Percentage of spontaneous plant >75%——1 Percentage of spontaneous plant 50%-75%——0.8 Percentage of spontaneous plant 25%-50%——0.4 Percentage of spontaneous plant <25%——0.2
	Ability to provide food for animals in plant communities (C6)	Percentage of plants in the plant communities that provide nectar, fruit and seeds > 75%——1 Percentage of plants in the plant communities that provide nectar, fruit and seeds 50%-75%——0.8 Percentage of plants in the plant communities that provide nectar, fruit and seeds 25%-50%——0.4 Percentage of plants in the plant communities that provide nectar, fruit and seeds < 25%——0.2
Degree of interference (B3)	Human activities (such as pruning, removing litter, replanting, and picking flowers, leaves, fruits and branches) (C7)	No human activities, or human activities promote the natural succession of plant communities. The impact on plant communities is within the scope of ecosystem regulating ability, and it has no impact on plant communities. ——1 Mild human activities, or human activities promote the natural succession of plant communities, and the impact on plant communities is within the scope of ecosystem regulating ability and has a slight impact on plant communities. ——0.8 Moderate human activities; the impact on plant communities is within the scope of ecosystem regulating ability, and it has a certain impact on plant communities. ——0.4 Severe human activities; the impact on plant communities is outside the scope of the ecosystem regulating ability, and it has a serious impact on the plant communities. ——0.2
	Natural disasters (such as diseases and insect pests, wind disasters and fires) (C8)	No natural disasters, and the plants grow naturally. ——1 Mild natural disasters; the impact on the plant communities is within the scope of ecosystem regulating ability, and it has a slight impact on the plant communities. ——0.8 Moderate natural disasters; the impact on the plant communities is outside the scope of ecosystem regulating ability, and it has a certain impact on the plant communities. ——0.4 Severe natural disasters; the impact on plant communities is outside of the scope of ecosystem regulating ability, and it has a serious impact on the plant communities. ——0.2
Plant community structure (B4)	Plant community planting design rationality (C9)	The plant disposition is excellent; the design of the planting bed is reasonable, and the planting density and interspecific competition of plants has been taken into account. ——1 The plant disposition is reasonable and the design of the bed is appropriate. The planting density and interspecific competition of plants are considered, but there is no reasonable distinction. ——0.8 The plant disposition is generally arranged the bed design is appropriate, and the plant planting density and interspecific competition are not considered.—0.4 The plant disposition is disordered; the design of the bed is unreasonable, and the planting density and interspecific competition are not considered. —0.2
	Plant community level (C10)	The overall landscape effect of the plant community is excellent. The proportion of plants in the vertical lines and horizontal lines of the plant community is obvious, and it has different landscape effects from different directions. ——1 The overall landscape of the plant community is good. The proportion of plants in the vertical lines and horizontal lines of the plant community is reasonable, and it has roughly different landscape effects from different directions. ——0.8 The overall landscape effect of the plant community is typical. The plants in the vertical lines and horizontal lines of the plant community can be distinguished, and there is no obvious difference in the distinction from different directions. ——0.4 The overall landscape effect of the plant communities is poor, and it is impossible to distinguish plants in the vertical and horizontal lines of the plant community. ——0.2
	Plant communities in coordination with environment (C11)	The plant community is well coordinated with the overall environment, and the boundary changes of the plant community are rich, providing an aesthetic sense of comfort and pleasure as a whole. ——1 The plant community has a relatively good coordination with the overall environment, and the boundary changes of the plant community are relatively good, providing an overall strong aesthetic sense of comfortable and pleasure. ——0.8 The coordination between the plant community and the overall environment is typical; the boundary changes of the plant community are not obvious. The overall aesthetic is typical. ——0.4 The plant community has poor coordination with the overall environment; the boundaries of the plant community have not changed, and an overall aesthetic sense of comfort and pleasure is not provided. ——0.2
Elements of plant community landscape (B5)	Seasonal variation richness (C12)	The plant community has obvious seasonal changes in four seasons with rich colors and natural features, and it has outstanding ornamental effects. —1 The seasonal variation of plant community in 2-3 seasons is obvious with relatively rich colors and natural features, and the ornamental effect is relatively good. ——0.8 The seasonal changes of plant communities are not obvious with monotonous color, and the ornamental effect is typical. ——0.4 The seasonal changes of plant communities are extremely insignificant; the color is monotonous, and there is no color transition or outstanding ornamental effect. ——0.2
	Ornamental plants richness (C13)	The types of the plant species are rich with beautiful plant morphology and have a variety of ornamental features. —— 1 The types of the plant species are relatively rich with relatively beautiful plant morphology and have a number of ornamental features. ——0.8 The types of the plant species are not quite rich; the plant morphology and the ornamental features are typical. ——0.4 The types of the plant species are few in the community and there is a lack of beauty in the plant morphology. The plants have poor ornamental characteristics

Table 6: Continue

Table 6: Continue

Elements of plant community configuration (B6)	Richness of plant life-form structure(C14)	The plant community has bulb flowers, herbs and ornamental grass and has evidently hiberarchy. The configuration is very reasonable;, and the overall aesthetic sense is excellent. ——1
		There are bulb flowers and ornamental grass in the plant community. The configuration is relatively reasonable; the levels are relatively demarcated, and the overall aesthetic sense is good. ——0.8
		There are bulb flowers in the plant community, and the configuration is not reasonable. The levels are not clear, and the overall aesthetic sense is typical.—0.4
		The plant life form is monotonous; the configuration is not reasonable; the levels are single, and the overall effect cannot indicate a sense of beauty. ——0.2
	Indicators for plant growth (C15)	The plants in the community have strong growth potential with no pests and diseases, normal leaf color and excellent ornamental effects. ——1
		The plants in the plant community have a relatively strong growth potential with no pests and diseases, normal leaf color and relatively good ornamental effects. ——0.8
		The plants in the plant community have poor growth potential with light pests and diseases and typical ornamental effects. ——0.4
		The plants in the plant community have very poor growth potential with severe pests and diseases, some plants on the verge of death and poor ornamental effects. ——0.2
Investment and Maintenance (B7)	Construction cost per unit area (C16)	Construction cost per unit area < 100——1
		Construction cost per unit area 101-140——0.8
		Construction cost per unit area 141-180——0.4
		Construction cost per unit area > 181——0.2
	Maintenance and management cost per unit area (C17)	Close to the "zero management and protection," Plant communities are naturally developed. ——1
		Relying on the material circulation and energy flow of the community itself, supplemented by timely management and protection measures. —0.8
		Management and protection is conducted several times a year on a regular basis. ——0.4
		Regular and high-frequency management, including weeding, pruning, spraying pesticides and applying fertilizers ——0.2
Social value (B8)	Closeness with humans (C18)	No isolation. Visitors can be completely closed; the planting density is moderate, and there are gardens, tables, chairs and other family facilities in the community or on the edge to provide a comfortable environment for human activities. ——1
		No isolation. People can enter it; the planting density is slightly higher, and there are family facilities around the community. ——0.8
		Obstacle isolation or high planting density. It is difficult for visitors to approach or enter the community. There are garden roads, tables and chairs around the community. ——0.4
		Complete isolation or extremely high planting density. Visitors cannot get close, and the garden can only be viewed from a distance. ——0.4

the relative importance value of u_{ij} to $u_j (j=1,2,3,\dots,n)$; the value of u_{ij} was established based on Table 7 and the interpretation matrix p was shown in Eq. (1).

$$P=\begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \dots & \vdots \\ u_{n1} & u_{n2} & \cdots & u_{nn} \end{bmatrix} \quad (1)$$

(3) Calculated importance ranking

According to the interpretation matrix, the eigenvector w corresponding to the maximum eigenvalue was obtained by the square root method, and the eigenvector w was the order of importance of the evaluation indicator, *i.e.*, the weight of each evaluation indicator. Based on Eqs. (2)-(4), the acquired $\overline{w}=\begin{bmatrix}\overline{w_1} & \overline{w_2} & \cdots & \overline{w_n}\end{bmatrix}^T$ was the weight vector.

$$M_i=\prod_{j=1}^{n} u_{ij} (i=1,2,3,\dots,n;\ j=1,2,3,\dots,n) \quad (2)$$

$$\overline{w_i}=\sqrt[n]{M_i} (i=1,2,3,\dots,n) \quad (3)$$

$$w_i=\frac{\overline{w_i}}{\sum_{i=1}^{n}\overline{w_i}} (i=1,2,3,\dots,n) \quad (4)$$

(4) Conducted consistency test

Finally, we calculated the maximum eigenvalue $\lambda_{\max}$ of the interpretation matrix (eq. 5). Next, eq. 7 was used to perform a consistency test on the interpretation matrix to determine whether the weight distribution was reasonable.

$$\lambda_{\max}=\sum_{i=1}^{n}\frac{(pw)_i}{nw_i}=\frac{1}{n}\sum_{i=1}^{n}\frac{(pw)_i}{w_i} \quad (5)$$

$$pw=\begin{bmatrix}(pw)_1 \\ (pw)_2 \\ \vdots \\ (pw)_n\end{bmatrix}=\begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \dots & \vdots \\ u_{n1} & u_{n2} & \cdots & u_{nn} \end{bmatrix}\times\begin{bmatrix}w_1 \\ w_2 \\ \vdots \\ w_n\end{bmatrix} \quad (6)$$

$$CI=\frac{\lambda_{\max}-n}{n-1} \quad (7)$$

$$CR=\frac{CI}{RI} \quad (8)$$

In the equations above, CI was the general consistency index of the interpretation matrix; RI (Table 8) was the average random consistency index, and the CR was the random consistency ratio. When CR < 0.10, the interpretation matrix was considered to pass the consistency test, indicating that the weights were reasonable. Otherwise, interpretation matrix was adjusted until the consistency met the requirements.

Through the construction of the judgment matrix (Table 9) and the process of hierarchical consistency test, the weights of the evaluation indices of the new naturalistic herb community landscape evaluation system based on the analytic hierarchy process were obtained (Table 10).

Score calculation of the evaluation index

Summarize the qualitative and quantitative indices, and calculate the standard scores of each index according to the method in Table 6. Then, eq. 9 was used to calculate the comprehensive score of new naturalistic herb community landscape.

Table 7: Value and meaning of interpretation matrix

Value	Meaning
1	The two factors are equally important
3	The u_i is slightly more important than the u_j
5	The u_i is obviously more important than the u_j
7	The u_i is strongly more important than the u_j
9	The u_i is extremely more important than the u_j
2,4,6,8	Values between the above groups
Reciprocal If the ratio of the importance of factor i to factor j is a_{ij}, then the ratio of factor j to factor i is $a_{ji}=\frac{1}{a_{ij}}$	

Table 8: Random index (RI)

N	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48	1.51

Table 9: The judgment matrix

B1-C	C1	C2	C3	C4	W	$\lambda_{\max}=4.0104$
C1	1	4	4	3	0.5477	$CR=0.0038<0.10$
C2	1/4	1	1	1	0.1471	
C3	1/4	1	1	1	0.1471	
C4	1/3	1	1	1	0.1581	
B2-C	C5	C6			W	$\lambda_{\max}=2$
C5	1	3			0.75	$CR=0<0.10$
C6	1/3	1			0.25	
B3-C	C7	C8			W	$\lambda_{\max}=2$
C7	1	2			0.6667	$CR=0<0.10$
C8	1/2	1			0.3333	
B4-C	C9	C10	C11		W	$\lambda_{\max}=3.067$
C9	1	3	3		0.5937	$CR=0.058<0.10$
C10	1/3	1	2		0.2493	
C11	1/3	1/2	1		0.1570	
B5-C	C12	C13			W	$\lambda_{\max}=2$
C12	1	4			0.8	$CR=0<0.10$
C13	1/4	1			0.2	
B6-C	C14	C15			W	$\lambda_{\max}=2$
C14	1	2			0.6667	$CR=0<0.10$
C15	1/2	1			0.3333	
B7-C	C16	C17			W	$\lambda_{\max}=2$
C16	1	3			0.75	$CR=0<0.10$
C17	1/3	1			0.25	
A1-B	B1	B2	B3		W	$\lambda_{\max}=3.009$
B1	1	2	3		0.5396	$CR=0.0053<0.10$
B2	1/2	1	2		0.2970	
B3	1/3	1/2	1		0.1634	
A2-B	B4	B5	B6		W	$\lambda_{\max}=3.067$
B4	1	3	3		0.5937	$CR=0.058<0.10$
B5	1/3	1	2		0.2493	
B6	1/3	1/2	1		0.1570	
A3-B	B7	B8			W	$\lambda_{\max}=2$
B7	1	1			0.5	$CR=0<0.10$
B8	1	1			0.5	
A-A	A1	A2	A3		W	$\lambda_{\max}=3.010$
A1	1	2	5		0.5815	$CR=0.05<0.10$
A2	1/2	1	3		0.3090	
A3	1/5	1/3	1		0.1095	

$$S=\sum_{i=1}^{n} w_i \times p_i (i=1,2,3,\ldots,n) \tag{9}$$

Where w_i is the comprehensive weight of the index layer (Table 9); p_i is the standard value of the i^{th} index, $w_i \times p_i$ is the index character value of study sampling points (Table 11) and S is the comprehensive value of the index system (Table 12). Finally, S is used as the basis for grading and is classified into I, II, III, IV, and V grades using the difference percentage method (Table 13).

Results

Diversity analysis of the herb communities

In this study, a total of 38 families and 88 species were collected. the results of the plant diversity analysis are

Table 10: Weight of each evaluation index

Index layer	Constraint layer								Weight
	B1	B2	B3	B4	B5	B6	B7	B8	
	0.3137	0.1727	0.0950	0.1835	0.0770	0.0485	0.0548	0.0548	
C1	0.5477								0.1718
C2	0.1471								0.0461
C3	0.1471								0.0461
C4	0.1581								0.0496
C5		0.75							0.1295
C6		0.25							0.0432
C7			0.6667						0.0633
C8			0.3333						0.0317
C9				0.5937					0.1089
C10				0.2493					0.0457
C11				0.1570					0.0288
C12					0.8				0.0616
C13					0.2				0.0154
C14						0.6667			0.0323
C15						0.3333			0.0162
C16							0.75		0.0411
C17							0.25		0.0137
C18								1	0.0548

shown in the Fig. 2. The maximum Simpson index was 0.8791, the minimum value was 0.7265, the mean was 0.8026, and the standard deviation was 0.0464. The variance was 0.0022. The Shannon-Wiener index had a maximum value of 2.2004, a minimum of 1.3660, a mean of 1.6980, a standard deviation of 0.2542 and a variance of 0.0646. The Pielou uniformity index has a maximum value of 0.9854, a minimum of 0.5254, a mean of 0.8662, a standard deviation of 0.0615 and a variance of 0.0038. The Patrick index had a maximum of 13, a minimum of 5, a mean of 8.88, a standard deviation of 2.6190, and a variance of 6.860. In 29.4% of the sampling points had recorded 5–7 kinds of herbs and 8–10 kinds of herbs were recorded in 41.2% of the sampling points and 29.4% of the sampling points were recorded in 11 or more kinds of herbs. When the Patrick index in the sampling points increases, the Simpson index and The Shannon-Wiener index tend to increase and The Pielou uniformity index tends to decrease. When the Patrick index increases from 5–7 to 11–13, the average value of the Simpson index rose from 0.7265 rose to 0.8791, while The Pielou uniformity index fell from 0.9854 to 0.7810 (Zhang *et al.* 2018).

The herb diversity was high. The Shannon-Wiener index of the herbs in each sampling points was quite different and the various indices were generally high. In terms of the construction of the herb communities, *Salvia leucantha*, *Dendranthema morifolium*, *Echinacea purpurea*, *Gomphrena globosa* and *Zinnia elegans* had a high frequency of application, resulting in high concentrations of herbs and low uniformity. The excessive use of one specific species can lead to the development of plant communities that feature one dominant species and excessive human activities can lead to the instability of the plant community diversity. A single plant composition mode reduces the plant diversity, weakens community resistance to external risks and renders the communities more vulnerable to external disasters.

The distribution of native plants and exotic plants was unbalanced. The exotic herb species in the herb communities studied accounted for 45.91% of the total herb species. Based on related research, the proportion of exotic plants in 54 cities of central Europe was 40.3% (Pyšek 1998), while that in the central and western United States was 19.3–45.7% (Clemants and Moore 2003). Due to the aesthetic needs of the city, it will introduce excellent exotic plant species for the plant community landscape. However, the large use of exotic plants may lead to the reduction of the application of native plants in the green space system, which will eventually lead to the reduction of landscape heterogeneity among different cities and the increase of the risk of plant invasion. The phenomenon of plant invasion was not obvious. Invasive plants often represent positive and negative effects in green space system. On the one hand, invasive species can improve the landscape effects of the green space system and generate economic benefits as economic plants for the rapid greening of wastelands. Alternatively, partially invasive or toxic alien invasive plants will have a negative impact on the indigenous biodiversity and become an unstable factor that threatens urban ecological security. In this survey, it was found that there were no obvious invasive species in the plant communities. This is because after the construction of the plant community is completed, the government departments invest a large amount of maintenance and management funds on the plant community and the influence of invasive species is artificially eliminated. At the same time, it was also determined that the plant communities in the surveyed areas had a higher degree of plant diversity; thus the stability of the plant community was also higher, which limited the ability of the invasive exotic species to mature to some extent.

Analysis of the comprehensive evaluation results of the new naturalistic herb community landscape

It can be concluded from the analysis that the scores of the 17 sampling points were between 0.32 and 0.65 (Fig. 3 and Table 12) and the sampling points with the lowest score of the new naturalistic herb community landscape evaluation was E. The plant community types of E sampling points are

Table 11: Index character value of study sampling points

Number of sampling points	Plant diversity				Plant community vitality		Degree of interference	
	Regional characteristics of plant communities (C1)	Simpson index of plant species (C2)	Shannon-Wiener index of plant species (C3)	Pielou uniformity index of plant species (C4)	spontaneous plant species (C5)	Ability to provide food for animals in plant communities (C6)	Human activities (C7)	Natural disasters (such as diseases and insect pests, wind disaster, fires, etc.) (C8)
A1	0.1151	0.0306	0.0338	0.0107	0.0416	0.0102	0.0430	0.0317
A2	0.0412	0.0000	0.0043	0.0061	0.0164	0.0157	0.0411	0.0317
B1	0.0309	0.0293	0.0273	0.0276	0.0151	0.0237	0.0487	0.0212
B2	0.0653	0.0117	0.0193	0.0000	0.0290	0.0169	0.0506	0.0257
C	0.0395	0.0232	0.0207	0.0276	0.0252	0.0085	0.0399	0.0241
D	0.0498	0.0266	0.0263	0.0254	0.0126	0.0169	0.0253	0.0317
E	0.0567	0.0010	0.0143	0.0002	0.0277	0.0085	0.0253	0.0250
F	0.0722	0.0186	0.0243	0.0099	0.0265	0.0254	0.0127	0.0254
G1	0.0962	0.0410	0.0461	0.0187	0.0252	0.0186	0.0127	0.0257
G2	0.1082	0.0372	0.0447	0.0162	0.0454	0.0309	0.0234	0.0241
H	0.0601	0.0371	0.0420	0.0116	0.0240	0.0254	0.0127	0.0254
I	0.0807	0.0461	0.0461	0.0423	0.0252	0.0254	0.0127	0.0254
J1	0.0911	0.0216	0.0296	0.0029	0.0479	0.0330	0.0228	0.0279
J2	0.0618	0.0287	0.0254	0.0381	0.0542	0.0376	0.0310	0.0307
K	0.0378	0.0039	0.0034	0.0257	0.0504	0.0169	0.0127	0.0254
L	0.0241	0.0040	0.0000	0.0496	0.0252	0.0085	0.0253	0.0254
M	0.0361	0.0298	0.0258	0.0390	0.0227	0.0085	0.0253	0.0254

Table 11: Continued

Number of sampling points	Plant community structure			Elements of plant community landscape		Elements of plant community configuration		Investment and Maintenance		Social value
	Plant community planting design rationality (C9)	Plant community level (C10)	Plant communities in coordination with environment (C11)	Seasonal variation richness (C12)	Ornamental plants richness (C13)	Richness of plant life-form structure (C14)	Indicators for plant growth (C15)	Construction cost per unit area (C16)	Maintenance and management cost per unit area (C17)	Closeness with humans (C18)
A1	0.0512	0.0243	0.0224	0.0302	0.0091	0.0091	0.0065	0.0136	0.0104	0.0433
A2	0.0479	0.0427	0.0315	0.0274	0.0048	0.0242	0.0070	0.0160	0.0133	0.0535
B1	0.0356	0.0196	0.0098	0.0217	0.0092	0.0116	0.0130	0.0333	0.0052	0.0535
B2	0.0445	0.0256	0.0189	0.0342	0.0099	0.0105	0.0102	0.0241	0.0053	0.0535
C	0.0890	0.0171	0.0252	0.0114	0.0028	0.0070	0.0107	0.0241	0.0133	0.0535
D	0.0668	0.0256	0.0126	0.0342	0.0085	0.0210	0.0067	0.0233	0.0045	0.0428
E	0.0445	0.0171	0.0063	0.0114	0.0057	0.0070	0.0070	0.0160	0.0053	0.0428
F	0.0890	0.0342	0.0252	0.0217	0.0142	0.0350	0.0175	0.0088	0.0029	0.0118
G1	0.0879	0.0346	0.0249	0.0222	0.0142	0.0350	0.0175	0.0076	0.0028	0.0096
G2	0.1113	0.0427	0.0252	0.0171	0.0142	0.0350	0.0175	0.0072	0.0024	0.0096
H	0.0890	0.0342	0.0252	0.0239	0.0142	0.0350	0.0175	0.0092	0.0031	0.0123
I	0.0890	0.0342	0.0252	0.0228	0.0114	0.0210	0.0140	0.0156	0.0025	0.0107
J1	0.1113	0.0427	0.0315	0.0285	0.0142	0.0350	0.0175	0.0068	0.0023	0.0091
J2	0.1113	0.0427	0.0315	0.0479	0.0142	0.0350	0.0175	0.0148	0.0047	0.0225
K	0.0668	0.0290	0.0189	0.0200	0.0053	0.0084	0.0109	0.0164	0.0028	0.0321
L	0.0223	0.0171	0.0063	0.0114	0.0028	0.0070	0.0070	0.0401	0.0106	0.0428
M	0.0445	0.0256	0.0126	0.0114	0.0028	0.0070	0.0100	0.0160	0.0027	0.0321

12: Landscape evaluation on herb communities of study sampling points

No.	Ecological features and sustainability	Landscape aesthetics	Social economy	Comprehensive score	Evaluation grade
A1	0.3168	0.1528	0.0673	0.5369	III
A2	0.1565	0.1854	0.0828	0.4248	IV
B1	0.2240	0.1204	0.0920	0.4363	IV
B2	0.2185	0.1538	0.0829	0.4553	III
C	0.2088	0.1632	0.0909	0.4628	III
D	0.2147	0.1754	0.0706	0.4606	III
E	0.1587	0.0990	0.0642	0.3218	V
F	0.2148	0.2368	0.0235	0.4751	III
G1	0.2841	0.2363	0.0200	0.5405	II
G2	0.3302	0.2630	0.0192	0.6124	II
H	0.2381	0.2390	0.0246	0.5018	III
I	0.3039	0.2176	0.0289	0.5503	II
J1	0.2768	0.2807	0.0182	0.5756	II
J2	0.3076	0.3001	0.0420	0.6497	I
K	0.1761	0.1592	0.0513	0.3866	IV
L	0.1620	0.0739	0.0935	0.3295	V
M	0.2124	0.1140	0.0508	0.3772	IV

Table 13: Evaluation grade

Evaluation score	≤0.32	0.32-0.42	0.42-0.52	0.52-0.62	≥0.62
Evaluation grade	V	IV	III	II	I

Penstemon campanulatus + *Verbena bonariensis* E sampling point is located on Shanghai Century Avenue with a score of 0.3218 and a comprehensive evaluation grade of Grade V. This is because Shanghai Century Avenue is

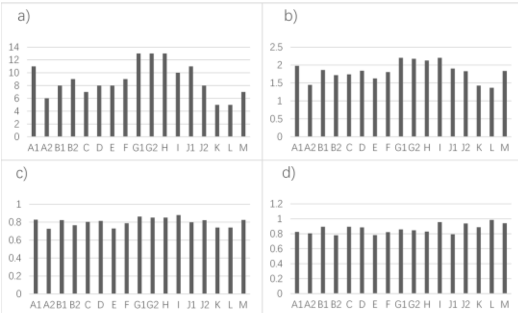

Fig. 2: Plant diversity analysis of survey sampling points. (**a**) Patrick Index; (**b**) Shannon-Wiener index; (**c**) Simpson index; (**d**) Pielou uniformity index

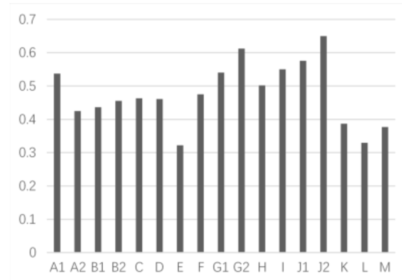

Fig. 3: Landscape evaluation of herb communities in the survey sampling points

located in the center of Shanghai Pudong District; the maintenance and management is frequent and there are relatively more human activities. The traffic volume around the site is very heavy, and the plant community is highly disturbed. To highlight its ornamental value, more flower varieties are used. The native plants are not effectively protected at the beginning of the planning. There are fewer native species in the plant community; the seasonal changes are extremely insignificant, and the color change of the plant community is monotonous. Therefore, the comprehensive score of this sampling point was the lowest. The sampling point with the highest score of the new naturalistic herb community landscape evaluation was J2 with a comprehensive evaluation score of 0.6479 and an evaluation grade of Grade I. This sampling point is located in the Suzhou Baitang Ecological Botanical Garden. Because the sampling point is located in the botanical garden, away from the road, with less human interference and a reasonable plant community arrangement, the cost of protection and management is also reduced. The species diversity of the plant community is very rich. The boundaries of the community are changeable; the seasonal changes of four seasons are obvious and the color and level variations of the plant community are rich. However, the types of native plants are still few, which was lowest score among all of its indices. Most of the scores were between 0.44 and 0.54 of Grade III, and the scores of six sampling points (sampling points A1, B2, C, D, F and H, respectively) were in this interval, accounting for 35% of the total sampling points. The plant communities in this grade of the sampling points were more balanced in the performance of various indices. There were four sampling points (sampling points G1, G2, I, and J1, respectively) with scores between 0.5 and 0.64 of Grade II. The plant communities in these sampling points have some common characteristics; namely the score of some indices was higher. For example, sampling points G1, G2 and J1 are all located near the West Lake in Hangzhou, and all of them have relatively high scores in the indices that include plant community planting design rationality, plant community levels, Plant communities in coordination with environment, Ornamental plants richness, Richness of plant life-form structure and Indicators for plant growth, because these sampling points are all located in the key landscape locations in the center of Hangzhou. At the beginning of the construction, a substantial amount of money was invested to maximize the aesthetic value of these plant communities resulting in a significantly lower score on social values. There were four sampling points (sampling points A2, B1, C and K, respectively) with scores between 0.4 and 0.44 of Grade IV. The plant communities of these sampling points have been built for a long time and some plants in the communities disappeared due to competition, which resulted in the reduction of plant diversity. The landscape aesthetic effects are also affected; therefore, the scores on all the indices were lower.

The comprehensive evaluation results of the new naturalistic herb community landscape are consistent with the actual situation. Its application and evaluation results are ideal, indicating that the evaluation model is operational, effective and practical. Therefore, the model can scientifically, objectively and realistically quantify and reflect the current situation of the new naturalistic herb community landscape and basically meets the requirements of the comprehensive evaluation of the new naturalistic herb community landscape.

Discussion

In this study, from the perspective of the multidisciplinary integration of ecology, aesthetics, horticulture, coenology, and landscape design aiming at the construction of a new naturalistic herb community landscape, with the combination of quantitative and qualitative analytical methods and based on the Analytic Hierarchy Process (AHP) method, a systematic, effective and scientific comprehensive evaluation index system was constructed. The new naturalistic herb community landscape evaluation system regards ecological features and sustainability, landscape aesthetics and social value as objective layers and forms 18 index layer on the basis of it. Moreover, the herb community landscapes in 17 sampling points from Shanghai, Hangzhou and Suzhou were thoroughly investigated. Herbs belonging to 38 families and 88 species were collected in total. Using the new naturalistic herb community landscape evaluation system to evaluate the herb communities in Shanghai, Hangzhou and Suzhou, the comprehensive scores of all the surveyed communities are between 0.34–0.65 and the evaluation grades are mostly concentrated in Grades II, Grade III and Grade IV (Fig. 4), which indicates that the overall quality of the plant communities studied was good (Feng 2014) and the overall evaluation results were ideal. but there are still some problems. These problems are as follows:

Spontaneous plant species are missing. Through field investigations of the herb community landscapes in the three cities of Shanghai, Hangzhou and Suzhou, it was found that the spontaneous plant species are seriously deficient in the composition of plant community, which has a substantial relationship with a lack of attention to the protection and utilization of native plants in the sites during urban planning and development. Native plants have completely adapted to the harsh natural environment of the city through long-term reproduction and evolution and can play a role in improving the stability of plant communities (James and Nelda 1998).

The species composition is not appropriate. There are significantly fewer native plants species in all plant communities. Based on the processing and analysis of the survey data, it was found that in all the sampling points surveyed, the types of native plants are few, with an average of only 1–2 species. In all the sampling points, sampling point K (SuZhou Songtao Street) had used the most native plant species. There are *Dendranthema morifolium*, *Dianthus chinensis* and *Coleus scutellarioides* accounting for 60% of all the plant species in sampling point K. There were 10 sampling points that had only one type of native plant, accounting for 59% of all the sampling points. There were three sampling points without native plants, accounting for 18% of all the sampling points. The sampling points with two or more than two native plants species only accounted for 23%. This is because the current landscape design overemphasizes the external visual effects of plant communities, excessively pursues formal beauty and a large number of colorful ornamental flowers introduced from abroad cause the loss of native plants and the regional characteristics are not obvious. On the whole, although the landscape aesthetics of the plant communities is improved, the ecological features and sustainability of the plant communities are reduced.

The plant diversity is relatively abundant, but the color matching of the plant communities is relatively monotonous, and the seasonal landscape is not prominent enough. The survey found that each sampling points include 5–13 plant species, and the plant varieties are abundant, but the plant configuration is unreasonable. The seasonal changes of most of the plant communities are not prominent enough. In spring and summer, when the plants are flowering, the landscape effect is better, but the effect in autumn and winter is not good and cannot show the seasonal changes and succession of the plant communities. These problems will affect the landscape benefits of the plant communities.

Maintenance and management is frequent, and the social value is low. Through surveys, it was found that most of the surveyed sampling points have different levels of isolation barriers, isolation nets and other isolation facilities to prevent artificial trampling and contact, which reduces the closeness of plant communities and humans. The new naturalistic herb community landscape should have some social value and play an educational role for ordinary people, so that people can connect with nature and learn to love it. At the same time, because of the lack of the universal application of the new naturalistic herb community landscape, most of the surveyed sampling points are located in the city's scenic areas, which play a role in improving the overall landscape of the city. Therefore, maintenance management is carried out on a regular basis. Excessive human disturbance leads to a decrease in the stability of the plant communities.

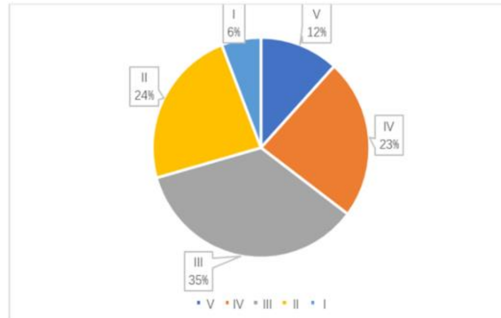

Fig. 4: Percentage of each evaluation grade of the survey sampling points

According to the summary of the problems existing in the landscape design of the new naturalistic herb community that are described above, related recommendations for constructing and arranging the landscape of the new naturalistic herb community are proposed as follows:

In the construction of the new naturalistic herb community landscape, attention should be paid to the protection and utilization of native plants and spontaneous plant (Hang 2017) The site should be fully investigated in the early stage of design, and the types and quantities of native plants and their locations in the base should be collected. In the design, these issues should be fully considered, and the plant community landscape design should be conducted in combination with the spontaneous plant. In addition, the use of native plants should be increased. The combination of native plants and exotic plants can provide richer plant diversity for plant communities. Native plants can also support richer animal diversity, moreover, increase the regional characteristics of plant communities and improve the flexibility of plant communities to survive urban disasters (Yuan and Du 2017).

A reasonable selection and disposition of plant varieties and excellent design of planting beds are the key point to the successful construction of plant communities (Wang *et al*. 2009). In the selection and disposition of plant varieties, the color matching and seasonal variation of the whole community, and the level and structure of the plant community should be considered. In excellent plant communities, each plant should appear in the position where they should appear, so that the interspecific competition between plants and the density of arranging plant communities can be reasonably solved, thereby improving the stability of plant communities.

In the soil preparation stage, appropriate treatments should be conducted. A reasonable amount of herbicides and organic fertilizers should be applied based on the soil environmental conditions to change the contents of N, P and K in the soil. This is beneficial to the growth of plants on the one hand. Alternatively, it can reduce the propagation and widespread growth of weeds, thus reducing the investment in post-conservation management. In the growth cycle of plant communities, it is also necessary to schedule the corresponding conservation and management, grasp the growth and development trends of the plant communities. It is necessary to remove overly competitive plants in a timely manner and replace plant varieties that have been eliminated due to competition.

Conclusion

As a current trend of plant landscape design, the new naturalistic herb community landscape design has greater development and utilization space for the future. As landscape architects, we should abandon the idea of quick success and instant benefit that is common in the current landscape design industry, and moreover, strengthen the contacts with horticulturists and ecologists to study and analyze the application of new naturalistic herb community landscape from a multidisciplinary perspective. In practice, we should not only focus on the current plant varieties but also increase the introduction, domestication, and reproduction of wild herbs and establish special seed factories to develop the exploitation and utilization of herbs in the direction of industrialization. Based on this, the development and application of the new naturalistic herb community landscape in the city will be promoted, thereby enhancing the landscape value of urban plant landscape and increasing the protection and utilization of urban plant diversity.

References

Chen B, Y Zheng, F Wang, N Li, JJ Jiang, S Lu (2016). Evaluation of plant community conservation in Ningbo city parks and optimized model construction. *J Zhej Inst Sci Technol Nat Sci Ed* 35:788–795

Clemants S, G Moore (2003). Patterns of species diversity in eight Northeastern United States cities. *Urban Habit* 6:4–16

Duan MJ, YR Wang, JF Xie, J Guo (2018). Scenic beauty estimation of Beijing urban park plant landscape by scenic beauty estimation method. *Sci Technol Eng* 18:45–52

Feng CY (2014). *Study on Close-to-nature Landscape Architecture and Evaluation System on its Plant Community*. Chinese Academy of Forestry, Beijing, China

Gou RK, X Zhao, YK Bu, T Gao, PX Zhao (2019). Dynamic study on the heat island effect and landscape pattern in urban area of Hangzhou. *Res Soil Water Conserv* 26:316–322

Hai Y, W Xue, PY Hao, L Dong (2012). Study on the microclimatic characteristics and human comfort of park plant communities in summer. *Proc Environ Sci* 13:755–765

Han JJ (2014). Landscape evaluation of plant communities based on APH and the analysis of plant arrangement modes. *Mod Landsc Archit* 11:3–7

Hang Y (2017). Development and application of herbaceous vegetation in new naturalistic ecological planting design. *Landsc Archit* 5:16–21

Hitchmough J, M Wagner (2013). The dynamics of designed plant communities of rosette forming forbs for use in supra-urban drainage swales. *Landsc Urban Plan* 117:122–134

Ikin K, AIT Tulloch, D Ansell, DB Lindenmayer (2018). Old growth, regrowth and planted woodland provide complementary habitat for threatened woodland birds on farms. *Biol Conserv* 223:120–128

James R, P Nelda (1998). A model of urban forest sustainability application to cities in the United States. *J Arboricult* 24:17–39

Li Z, D Chen, S Cai, S Che (2018). The ecological services of plant communities in parks for climate control and recreation-A case study in Shanghai, China. *PLoS One,* 13:1–18

Nagase A, N Dunnett (2013). Performance of geophytes on extensive green roofs in the United Kingdom. *Urban For Urban Green* 12:509–521

Pan GL (2012). Study on evaluation and optimal disposition about ecological plant community of urban parks in Hefei. Thesis, *Shanghai Jiao Tong University*, Shanghai, China

Pyšek P (1998). Alien and native species in central european urban floras: A quantitative comparison. *J Biogeogr* 25:155–163

Shi Y, XM Tang (2018). Evaluation on plant community in Shanghai 100-meter green belt. *J Shanghai Jiaotong Univ Agric Sci* 36:28–35

Siqueira M, I Schmidt, A Sampaio, A Robredo, A Zhang, X Lu (2017). More than trees. *Landsc Archit Front* 5:144–153

Smith LS, MEJ Broyles, HK Larzleer, MDE Fellowes (2015). Adding ecological value to the urban lawnscape. Insect abundance and diversity in grass-free lawns. *Biodivers Conserv* 24:47–62

Smith RM, PH Warren, K Thompson, KJ Gaston (2006a). Urban domestic gardens (VI): environmental correlates of invertebrate species richness. *Biol Conserv* 15:2415–2438

Smith RM, KJ Gaston, PH Warren, JG Hodgson, PH Warren, KJ Gaston (2006b). Urban domestic gardens (IX): composition and richness of the vascular plant flora, and implications for native biodiversity. *Biol Conserv* 129:312–322

Wang W, Y Xu, H Wang (2018). Adaptability of flower border plants based on AHP method in Shenzhen: Taking Honghu park flower border plants for example. *Guangdong Landsc Archit* 40:45–50

Wang YC, LY Han, CP Wang (2009). *Ecological Design of Community*. China Architecture and Building Press, Beijing, China

Wang ZH, XX Zhao, JC Yang, JY Song (2016). Cooling and energy saving potentials of shade trees and urban lawns in a desert city. *Appl Ener* 161:437–444

Wei, L.L. and Y.S. Chen, 2015. AHP-based evaluation on flower border plant landscape of city parks in Xuzhou. *J. Fuj. For. Sci. Technol.,* 42: 160–165

Woźniak E, S Kulczyk, M Derek (2018). From intrinsic to service potential: An approach to assess tourism landscape potential. *Landsc Urban Plan* 170:209–220

Xie TN, JL Li, ZG Sun, G Mao, HM Pu, ZG Li, HP Qin, YF Chen, C Xu (2015). Progresses of resources investigation, dynamic monitoring and conservation of plant species diversity in Suzhou, China. *Tianj Agric Sci* 21:28–33

Yang M, XM Ji, WL Ji, ZL Ouyang (2015). Landscape evaluation for plant communities of urban parks in Xi'an. *J Northwest For Univ* 30:289–294

Yuan J, CL Du (2017). The application and design of the new naturalistic herbaceous planting in urban rain gardens. *Landsc Archit* 5:22–27

Zeng F, XW Li, XM Hu, HF Chen (2014). Landscape evaluation of typical garden plant communities in Baiyun Mountain scenic site of Guangzhou. *Chin Landsc Archit* 30:97–101

Zhang N, L Dong, D Wang, K Wang (2018). Survey and Analysis of the Composition and Distribution Pattern of Herbaceous Plants in Beijing Urban Ecological Corridors. *Chin Landsc Archit* 6:94–99

Zhao JJ, ZY Ouyang H Zheng, WH Xu, XK Wang, YM Ni (2009). Proposed procedure in designing and planning stratified random selection investigation of urban vegetation. *Chin J Ecol* 28:1430–1436