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REVIEW ARTICLE

Species diversity of typical forest communities in Taizhou Green Heart zone

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ABSTRACT

Taking six typical forest communities in Taizhou Green Heart (i: Liquidambar formosana + Ulmus pumila + Celtis sinensis; ii: Celtis sinensis + Pterocarya stenoptera + Pinus massoniana; iii: Sapindus mukorossi + Sapium sebiferum + Cupressus funebris; iv: Liquidambar formosana + Acer buergerianum + Cupressus funebris); v: Celtis sinensis + Ligustrum compactum + Pinus massoniana; vi: Machilus ichangensis + Sapindus mukorossi + Acer buergerianum) as the research objects, 5 indicators: Shannon-Wiener (H), Patrick richness (R1), Margalef species richness (R2), Pielou evenness (J) and ecological dominance (D) were used to analyze species diversity in forest communities. The results showed that: (1) the community was rich in plant resources, with a total of 50 species belonging to 40 genus and 31 families, including 19 species in tree layer, 22 species in shrub layer and only 9 species in herb layer, few plant species; (2) the species richness and diversity index of tree layer and shrub layer were significantly higher than that of herb layer, but there were differences among different communities in the same layer, and no significant difference was reached; (3) the species richness and community diversity of the six communities showed as follows: community VI > community I > community II > community IV > community V > community III.

Keywords: Forest Community; Species Diversity; Ecological Landscape Forest; Taizhou Green Heart

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1. Introduction

Forest community structure and species diversity are one of the most important contents and hotspots in ecological research[1]. Species diversity is an important part of biodiversity[2]. Species diversity not only reflects the richness, variation and evenness of species in a community or habitat, but also reflects the type of community structure, organization level, development stage, degree of stability and habitat differences[3-5]. The investigation and research on forest community structure and determination of species richness and diversity index of community are conducive to better knowing the composition, structure, function and dynamics of the community, understanding the living conditions of the species, grasping the general rule of community succession and the formation mechanisms of the biological diversity, so as to provide theoretical basis for biodiversity protection[6].

The urban forest in the Green Heart zone of Taizhou has huge ecosystem service value and plays an important role in climate regulation, environmental protection, water conservation, soil and water conservation, windbreak and sand fixation, sightseeing and recreation, and beautification of the city, etc. It is an important part of the ecological environment construction of Taizhou[7,8]. This research takes planted forests around Jiufeng Mountain, Dayue mountain and Shizi Mountain,

as investigation objects, investigating and analyzing the community characteristics and plant diversity, understanding the community structure and species diversity status and further analyzing the stability of community and ecological benefits, so as to provide basic information for the construction, planning and stand transformation of ecological landscape in the Green Heart zone, scientific basis for the conservation and sustainable utilization of forest vegetation species diversity as well as references for the protection and development of Taizhou Green Heart zone.

2. Overview of the study site

Taizhou is located in the central coastal area of Zhejiang Province. It is a "combined coastal city with green ring and heart shape". Green Heart is located in the center of urban area and is the core of urban spatial structure. The total area is about 6,333 hm^2, of which 3,466 hm^2 is hill. Mountains and hills occupy nearly 50% of the land, and mainly composed of Jiufeng Mountain, Dayue Mountain and Shizi Mountain. The highest peak in the area is Huangmao Shan of Jiufeng Mountain, with an altitude of 529.2 m, and there are four peaks above 500 m in height, all of which concentrated in Jiufeng Mountain in the west. The mountainous area with low hills and gentle slopes in Green Heart is about 10.31 km^2, in which the slope of 5°–15° are about 3.74 km^2 and that of 15°–25° are about 6.57 km^2. The study site is centered on Jiufeng Mountain, including some sample sites of Danyue Mountain and Shizi Mountain. The average annual temperature in the sample area is 16.6–17.5 ℃, and the average annual precipitation is 1,480–1,530 mm, which belongs to the typical subtropical monsoon climate. The soil is mainly yellow soil, red soil and so on. The main vegetation types are subtropical evergreen broad-leaved forest and subtropical Zhejiang-Fujian hill forest.

3. Research methods

3.1 Survey methods

From December 2013 to June 2014, a comprehensive survey of Jiufeng Mountain, Dayue Mountain, Shizi Mountain and other mountains in Green Heart of Taizhou was conducted. It's found that there were few original evergreen broad-leaved forests and were mainly artificially cultivated landscape forests. Due to the influence of human activities, the species of understory shrubs and herbaceous plants are rare, and the forest community structure is relatively simple. According to the species and quantity of plants in the tree layer, the forest communities were divided into six typical community types: *Liquidambar formosana* + *Ulmus pumila* + *Celtis sinensis* (i); *Celtis sinensis* + *Pterocarya stenoptera* + *Pinus massoniana* (ii); *Sapindus mukorossi* + *Sapium sebiferum* + *Cupressus funebris* (iii); *Liquidambar formosana* + *Acer buergerianum* + *Cupressus funebris* (iv); *Celtis sinensis* + *Ligustrum compactum* + *Pinus massoniana* (v); *Machilus ichangensis* + *Sapindus mukorossi* + *Acer buergerianum* (vi). According to different community types, sampling method was used to investigate typical sample sites selected. Three tree quadrats of 20 m × 20 m were set up in each community, within which five 4 m × 4 m shrub quadrats and five 1 m × 1 m herbaceous quadrats were set, a total of 18 tree quadrats and 90 shrub and herbaceous quadrats were set. Each tree's name was recorded, and their diameter at breast height (DBH), tree height, crown width and other growth indexes were measured. Investigate and record the name, plant height, coverage, etc. of shrub and herb were investigated and recorded. In the sample site investigation, trees with DBH ≥4 cm were selected to measure the species diversity of the tree layer, while trees with DBH ≤2 cm were excluded from the calculation range of the diversity index of the tree layer, and young trees and seedlings were recorded in the shrub layer[9,10].

3.2 Data analysis

3.2.1 Species importance value

Significant value of trees (iv_{tree}) = (relative density (%) + relative significance (%) + relative frequency (%))/3; significant value of shrub and herb ($iv_{shrub\ and\ herb}$) = (relative density (%) + relative coverage (%) + relative frequency (%))/3. In the equation, relative density refers to the percentage of individuals of a certain species in the sum of individuals of all species; relative significance refers to

the percentage of the chest height area of a species (1.3 m above the ground) in the total chest height area of all species; relative frequency refers to the percentage of the number of quadrats of a certain species in the total number of quadrats; coverage refers to the land area covered by the vertical projection of the above-ground part of plants[11,12].

3.2.2 Indicators of species diversity

In this study, several widely used measures methods were used[12-14]: (1) index of species diversity (Shannon-Wiener index), $H = -\sum P_i \ln P_i$; (2) Patrick richness index, $R_1 = S$; (3) Margalef species richness index, $R_2 = (S - 1)/\ln N$; (4) Pielou uniformity index, $J = H/\ln S$; (5) Ecological dominance index, $D = 1 - \sum P_i^2$. In the equation, P_i is the percentage of the number of individuals of a certain species in the community to the total number of individuals of all species in the community, that is, $Pi = N_i / N$, N_i is the number of the i^{th} species; N is the total number of individuals in the community; S is the number of species in the community.

3.2.3 Statistical analysis

For the calculated diversity indicators of different forest community types, the overall diversity differences of different community types and diversity differences at various vertical levels were compared through statistical analysis. One-way ANOVA and multiple comparison (Duncan) were used for analysis. Excel and SPSS 13.0 software were used for calculation.

4. Results and analysis

4.1 Species composition of forest communities

Species composition is one of the most basic characteristics of plant communities, and is the basis of community composition[15], affecting the biodiversity of forest communities. There were a total of 50 species of vascular plants in 40 genera and 31 families, including 5 species of ferns belonging to 4 families and 4 genera, 3 species of gymnosperms belonging to 3 families and 3 genera and 42 species of angiosperms belonging to 33 genera and 25 families. The dominant families were *Ulaceae*, *Lauraceae*, *Fagaceae*, *Jugaceae* and *Ilexaceae*. There were 19 species in the tree layer plants, 22 species of shrub layer plants and only 9 species in herbaceous layer. It shows that there are more plants in tree layer and shrub layer, whose species are more abundant.

4.2 Characteristics of dominant species in community

Importance values can better reflect the position and role of different plants in the community, as well as the differences in the composition and structure of different plant communities[16,17]. In the investigation, it was found that the vertical layer of plants was obvious, and the tree layer and shrub layer were dominant, while the herb layer was weak. In the community, the dominant tree species in the tree layer were obvious, such as *Celtis sinensis*, *Ulmus parvifolia*, *Sapium sebiferum*, *Liquidambar formosana*, *Pterocarya stenoptera*, *Sapindus mukorossi* and *Cupressus funebris* etc. **Table 1** showed that the importance values of *Liquidambar formosana*, *Cupressus funebris* and *Pinus massoniana* were relatively high and played an important role in the community, serving as the building species and dominant species in the community; while the importance value of *Metasequoia glyptostroboides* and *Celtis julianae*, etc. were smaller. Du Ying and Chestnut are also occasionally seen in the tree layer, which are not listed due to their small importance value. The differences of dominant species in shrub layer were not obvious (**Table 2**), which mainly including young trees and seedlings in tree regeneration layer, such as *Celtis sinensis*, *Acer buergerianum*, *Ulmus pumila*. In addition, shrubs with higher important values include common under-forest shrubs such as *Castanea seguinii*, *Rhus chinensis*, and *Loropetalum chinense*, as well as *Trachelospermum jasminoides* and *Parthenocissus tricuspidata*. There are few plant species in the herb layer, but the dominance is more obvious (**Table 3**). In the sample sites with lower altitudes, the main species are *Pteris multifida* and *Mercurialis leiocarpa*, and their important values are 22.43 and 15.59, while in the quadrats with higher altitudes, ferns such as *Dicranopteris pedata* and *Dryopteridaceae* are dominant.

Table 1. Importance values of common plants in tree layer %

No.	Plant name	Relative density	Relative frequency	Relative significance	Importance value
1	*Liquidambar formosana*	9.09	10.1	13.62	10.94
2	*Cupressus funebris*	9.79	11.9	10.75	10.81
3	*Pinus massoniana*	7.69	9.8	13.40	10.30
4	*Celtis sinensis*	11.19	10.5	7.88	9.86
5	*Pterocarya stenoptera*	6.99	9.7	9.46	8.72
6	*Acer buergerianum*	9.12	10.2	5.92	8.41
7	*Pinus thunbergii*	6.99	8.5	7.39	7.63
8	*Machilus ichangensis*	5.59	8.4	7.41	7.13
9	*Sapindus mukorossi*	6.29	8.3	6.37	6.99
10	*Sapium sebiferum*	6.29	8.4	5.29	6.66
11	*Ulmus pumila*	5.59	6.4	4.87	5.65
12	*Celtis julianae*	4.90	5.2	4.84	4.98
13	*Metasequoia glyptostroboides*	2.80	4.1	3.27	3.39

Table 2. Importance values of plants in shrub layer %

No.	Plant name	Relative density	Relative frequency	Relative significance	Importance value
1	*Celtis sinensis*	7.01	10.30	9.29	8.87
2	*Acer buergerianum*	7.69	8.65	8.36	8.23
3	*Castanea seguinii*	5.95	9.89	8.46	8.10
4	*Rhus chinensis*	10.82	7.06	5.88	7.92
5	*Ulmus parvifolia*	6.86	10.10	6.77	7.91
6	*Trachelospermum jasminoides*	5.13	8.41	8.44	7.33
7	*Trachycarpus fortune*	5.85	5.90	8.03	6.59
8	*Loropetalum chinensis*	6.41	6.80	5.22	6.14
9	*Ligustrum compactum*	6.50	5.20	5.59	5.76
10	*Weigela florida*	6.63	5.90	4.65	5.73
11	*Lindera glauca*	3.56	6.01	5.06	4.88
12	*Parthenocissus tricuspidata*	2.89	5.78	4.82	4.50
13	*Elaeagnus pungens*	3.24	6.31	3.91	4.49
14	*Broussonetia papyrifera*	2.56	5.32	4.47	4.12
15	*Aralia chinensis*	3.85	4.72	3.76	4.11
16	*Quercus aliena*	2.23	4.06	4.47	3.59
17	*Aphananthe aspera*	2.35	5.20	2.60	3.38
18	*Ilex latifolia*	1.94	4.16	2.59	2.90
19	*Rosa multiflora*	2.19	3.83	2.93	2.98
20	*Osmanthus fragrans*	1.28	2.48	1.41	1.72
21	*Serissa japonica*	0.97	1.37	0.47	0.94

Table 3. Importance values of plants in herbaceous layer %

No.	Plant name	Relative density	Relative frequency	Relative significance	Importance value
1	Pteris multifida	20.11	35.12	12.07	22.43
2	Mercurialis leiocarpa	10.58	25.57	10.62	15.59
3	Dicranopteris dichotoma	8.47	18.39	15.52	14.12
4	Dryopteris decipiens	8.47	10.18	18.97	12.54
5	Ophiopogon bodinieri	8.56	8.64	8.34	8.51
6	Parathelypteris glanduligera	5.82	1.65	12.07	6.51
7	Cayratia japonica	4.41	3.48	6.90	4.93
8	Farfugium japonicum	5.42	2.88	5.63	4.64
9	Oxalis corniculata	2.23	1.83	3.90	2.65

4.3 Species diversity analysis

4.3.1 Comparison of overall diversity among different levels

Species diversity represents the basic characteristics of community organization level and function, and reflects the evenness of species number distribution[11]. In order to better understand the diversity of forest communities in Green Heart of Taizhou, Simpson ecological dominance index, Margalef richness index, Shannon diversity index and Pielou evenness index were used to describe the species diversity of different communities. The results showed that (**Table 4**): the variation trends of the five diversity indexes in the community were consistent, and the overall degree of diversity was shrub layer > tree layer > herb layer, which was consistent with the results of Xu *et al.*[18] on the forest community diversity of the ous broad-leaved forest community in Longwang Mountain. The shrub layer is rich in species and quantity, so its species richness and diversity are significantly higher than those in the tree layer and

herb layer. The diversity index of the herb layer was lower than that of the tree layer and the shrub layer. This was because the canopy density of the community was relatively high and the understory light was insufficient, forming a shady, closed and humid niche. Therefore, the herb layer was sparse and had few species, so the species richness and diversity of the herb layer were significantly lower than that of the tree layer and the shrub layer.

Table 4. Comparison of the difference significance of the overall diversity index among different levels

Layers	R_1	R_2	H	D	J
Tree layer	10.833b	3.062a	2.273b	0.887a	0.958a
Shrub layer	15.330a	3.511a	2.564a	0.904a	0.957a
Herb layer	7.167c	1.423c	1.730c	0.796b	0.901b

*: Different letters in the same column are significant difference. Same as below.

The difference significance test and multiple comparison were conducted for the overall diversity of tree layer, shrub layer and herb layer (**Table 4**). The results showed that the species richness index (R_1) and diversity index (H) were consistent among different layers, and both were significantly different at different layers. Shrub layer and tree layer were significantly higher than herb layer. However, the differences of richness index (R_2), dominance index (D) and evenness index (J) of tree layer and shrub layer were not significant. From the Pielou evenness index, both tree layer and shrub layer were significantly higher than that of herb layer, indicating that the distribution of tree layer and shrub layer was basically uniform in the community, while the distribution of herb layer was not, but distributed in clusters and slices, which was determined by the life type of plant species in herb layer.

4.3.2 Analysis of species diversity difference in different communities

This paper compared five diversity index of six different communities, and the results were shown form **Figure 1** to **Figure 5**. As can be seen from **Figure 1** to **Figure 3**, the richness (R_1, R_2) and Shannon-Wiener (H) index of tree layer and shrub layer in community VI (*Machilus ichangensi* + *Sapindus mukorossi* + *Acer buergerianum*) were

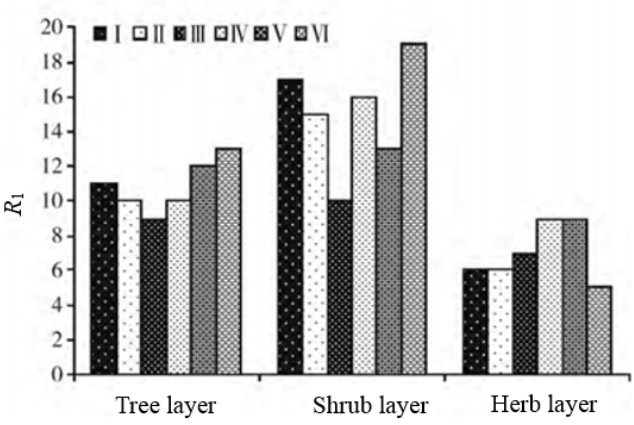

Figure 1. Patrick richness index.

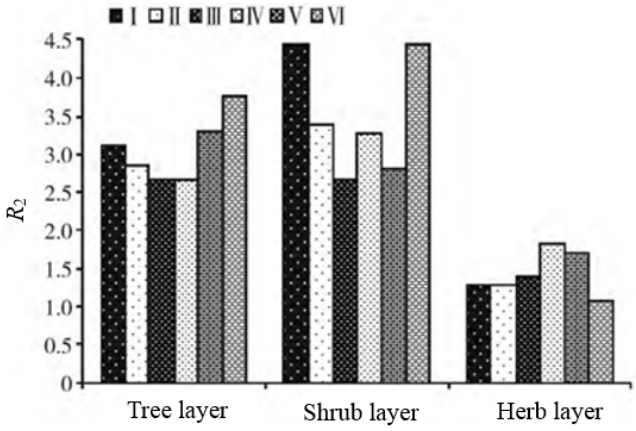

Figure 2. Margalef richness index

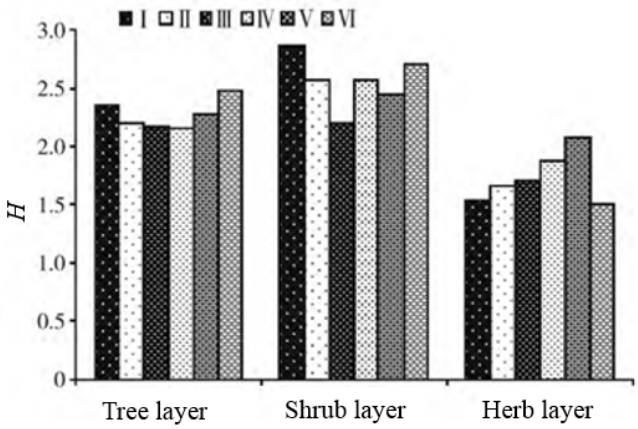

Figure 3. Shannon-Wiener index.

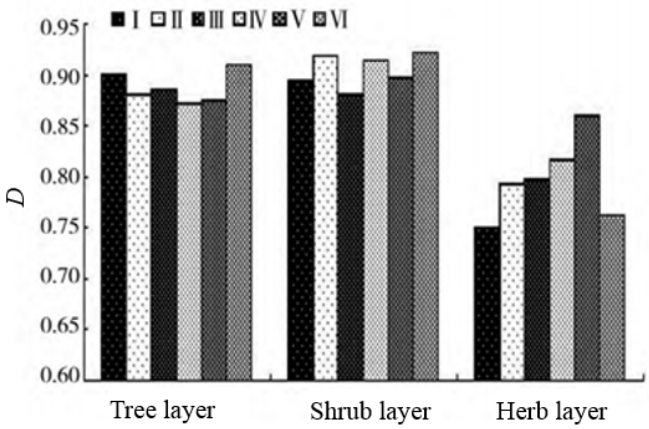

Figure 4. Ecological dominance index.

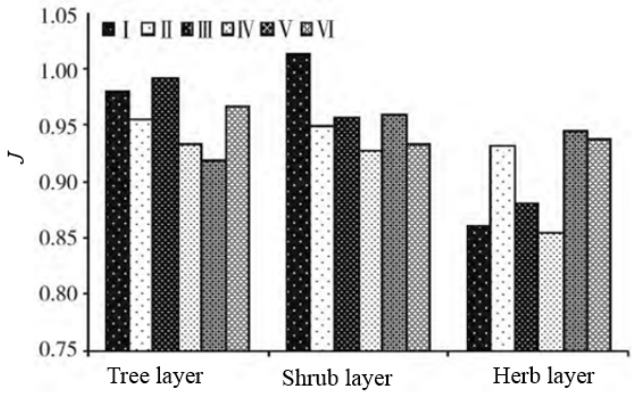

Figure 5. Pielou uniformity index.

higher, while the herbaceous layer was the lowest among the six communities. This may be related to the location of community. Community VI is located on the edge of road with a low altitude and serious human trampling phenomenon, which greatly reduces the species richness and diversity level of herbaceous layer of community. On the contrary, R_1, R_2 and H index of tree layer and shrub layer were the lowest in community III (*Sapindus mukorossi* + *Sapium sebiferum* + *Cupressus funebris*)), indicating that species richness and diversity of community were low, while indexes of herb layer showed little difference from other communities.

The species richness and community diversity of the six communities showed as follows: community VI > community I > community II > community IV > community V > community III.

Pielou evenness index reflects the evenness of species distribution in a community. Even distribution of species in a community means that the degree of dominance is not concentrated or dominant phenomenon is not obvious. In **Figure 4** and **Figure 5** there was little difference in ecological dominance index and Pielou index among different communities. Only J index of shrub layer of community I showed a large value, which was significantly higher than that of other communities, indicating that shrub layer of this community had obvious population dominance and the community was in a stable development stage.

5. Conclusions and discussion

5.1 Forest community and the present situation of biological diversity in Taizhou Green Heart zone

Through the structure investigation of typical forest community in in Taizhou Green Heart zone, and the analysis of different species composition and species diversity index, the results show that there are have higher richness and diversity in tree layer and shrub layer of forest communities, and each index is significantly greater than the herb layer. In the tree layer, the canopy width and DBH of plants were larger, the species were less, the spacing of plants was larger, and the canopy density was higher. The shrub layer has the largest number of plants, and most of the species are similar to the tree layer. The plants are mainly grown under natural succession, without obvious dominance, but the density is relatively large, which can make full use of space, and has certain significance for the stability of community. Due to the poor light conditions under the forest, the number of herbaceous species is small, and most of them are ferns or some herbaceous climbing plants that can tolerate the shade and humidity. Due to the influence of altitude, geographical location and other factors, the phenomenon of artificial trampling of understory herbaceous layer is serious, which greatly reduces the species richness and diversity of understory herbaceous layer.

5.2 Influence of the present situation of forest community biodiversity on the construction of ecological landscape forest in Green Heart zone

Ecological landscape forest is an afforestation system and forest ecosystem mainly based on ecological public welfare forest, which plays an important role in climate regulation, environmental protection, water conservation, soil and water conservation, wind prevention and sand fixation, recreation and beautification of the city. The construction of ecological landscape forest is a new direction of modern urban forestry development and has become an important part of ecological environment construction in China.

Therefore, it's an urgent matter to build and construct ecological landscape forest in the Green Heart zone, and carry out protective development of Green Heart so as to improve the air quality and ecological environment of the main urban area in

Taizhou, and create a good leisure and health care space for the citizens. According to the survey, the forest vegetation in Green Heart area of Taizhou, centered on Jiufeng Mountain, is dominated by artificial forest, with less original evergreen broad-leaved forest, simple structure and poor community stability. Therefore, the effective protection of forest resources and the improvement of community structure in this area are of great significance to the ecological function of Green Heart.

According to the current situation of the forest vegetation of Green Heart mastered in this research, the community VI with better biodiversity, namely the Machilus ichangensis + *Sapindus mukorossi* + *Acer buergerianum*) community should be used as the typical community type, and under-forest shrubs and shade-tolerant grasses such as *Trachelospermum jasminoides*, *Hedera helix, Reineckia carnea*, Fatsia japonica and ferns, etc. should be appropriately replanted to further enrich the community structure. Due to the lack of tree species in most communities, it is suggested to replant tall trees such as *Schima superba*, *Lithocarpus*, *Cryptomeria, Quercus acutissima*, *Phoebe chekiangensis*, *Phoebe sheareri*, *Machilus thunbergii*, *Machilus leptophylla*, *Quercus glauca Thunb*, etc., deciduous trees such as *Metasequoia glyptostroboides*, *Taxodium ascendens*, etc. should also be planted, so as to enrich different seasonal landscapes. In general, broadleaf forest was the main ecological landscape, supplemented by bamboo and coniferous forest. From a functional point of view, ecological conservation should be the main type, which should be mainly distributed on the top of the mountain with Jiufeng Mountain as the main body. According to the gradual decrease of altitude, the forest structure mode with leisure health care mainly based on the leisure and health care type should be arranged respectively to create a good leisure environment for citizens. In the surrounding area of the Green Heart, forest land mainly protected by the Green Heart can be arranged, and ecological shelterbelt can be built to prevent the land around the Green Heart from being encroached by the surrounding land. In a word, the construction of Green Heart ecological landscape forest should be combined with the structural characteristics and habitat conditions of forest community, take the principle of Green Heart protective development as the principle, implement ecological management measures and means such as "building, replenishing, modifying, thinning and cultivating" according to local conditions, optimize the allocation of community plants, and gradually improve the forest community structure. From the perspective of ecosystem, we should create a stable and healthy forest ecosystem with aesthetic value, gradually improve the forest landscape value and ecological function, and further bring into play the ecological benefits of urban forest in Green Heart zone.

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Conflict of interest

No conflict of interest was reported by the author.

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