Chapter 42
Green Space Factor Assessment of High-Rise Residential Areas in Harbin, China

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Abstract As an important part of urban green space, how to effectively guide the improvement of the ecological benefits of residential green space has become one of the important issues in current residential planning. Western countries such as Germany, Sweden, and the United States have successively used the "Green Space Factor" as a tool for ecological assessment, while in China's settlement planning, there is only one greening rate indicator as a guide. Based on the Green Factor of Seattle, USA, this study used Harbin high-rise residential area as the research object to establish a Green Space Factor assessment tool for Harbin. The evaluation indicators were screened, adjusted and assigned through expert questionnaires. Finally, an evaluation system with five categories and 25 evaluation indicators was established. Subsequent assessments of the ecological benefits of the selected nine high-rise residential areas were evaluated. From the evaluation results, it can be found that the advantages and disadvantages of the ecological benefits of the settlements are directly related to the allocation of the landscape elements in the settlements and have a certain relationship with the greening rate and the volume ratio of the settlements. The settlements with high volume ratio and low greening rate can adjust the landscape elements. The configuration can also achieve high ecological benefits. This study can provide strong support for guiding the construction of green infrastructure in high-rise residential areas in cold cities.

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42.1 Introduction

At present, in large- and medium-sized cities in China, due to the tightness of land resources and the government's policy of intensive land use, high-rise settlements have become the mainstay of newly built residential areas. Therefore, how to effectively improve the ecological benefits of green areas in high-rise residential areas has become one of the important issues that need to be solved in the planning of high-rise residential areas today [1–4].

The Green Space Factor is a series of mandatory assessment tools for urban green space ecological benefits implemented by some governments in foreign cities [5]. There is only one two-dimensional control index of "Greening Rate" on the evaluation index system of urban residential areas in China. It is only possible to achieve the planar greening effect as a whole and cannot judge the actual three-dimensional greening structure and the ecological benefits of the green space [6, 7]. Therefore, it is necessary to establish a three-dimensional evaluation index that can fully reflect the spatial structure of residential green space as a supplement to the current two-dimensional green space index [8–11]. In order to assess the ecological benefits of landscape green space in high-rise residential areas in Harbin. It provides a theoretical basis for the assessment of green space factors in high-rise residential areas in cold cities and guides the construction of landscaped green spaces in other areas of China.

42.2 Literature Review

Although the naming of Green Space Factor tools is different in different countries, the evaluation method is roughly the same as the purpose [12]. In 1997, Berlin implemented the "Biotope Area Factor" assessment tool to guide the construction of urban green infrastructure [13–15]. Subsequent Green Space Factors began to be implemented in several western cities, typically including the Malmö Green Space Factor in Sweden [16], Seattle Green Factor [17], US Fife Green factor, and so on [18].

The Seattle Green Factor is the Green Space Factor with the most comprehensive application and the widest impact. It is based on the Biotope Area Factor, and it has a direct impact on the construction of Green Space Factor indicators in other cities in the United States [19, 20]. Compared with other Green Space Factors, Seattle Green Factor has more detailed evaluation indicators and more scientific evaluation criteria. The goal of Seattle's green factor building is to optimize the appearance of the community; reduce stormwater runoff; regulate urban microclimates, reduce heat island effects; provide habitat for birds and beneficial insects; reduce urban crime rates [21].

At present, the localization and modification of the Green Space Factor in China only stay in the prospect of research in this field. This paper aims to draw on the western countries' restrictions on urban space green space construction and guidance methods as well as the reference to the "Seattle Green Factor" assessment method, combined with the actual situation of Harbin high-rise residential areas, to establish a tool for assessing the ecological benefits of urban settlements. The aim is to reduce the urban heat island effect, provide habitat for animals and plants, and improve the thermal factors in the settlement [22–24].

42.3 Methodology

42.3.1 Seattle Green Factor Assessment Method

The elements of the Seattle Green Factor Assessment are divided into 7 categories, with a total of 21 assessment indicators. According to the level of ecological benefits provided by the corresponding weight assignment, the weight value is between 0.0 and 1.0. The Seattle Green Factor evaluation formula is SGF = (landscape element 1 area × score coefficient 1 + landscape element 2 area × score coefficient 2 + ⋯ landscape element N area × score coefficient N)/total Land area. In the process of evaluation, if the landscape elements of the same plot meet the requirements of multiple evaluation elements, then the various landscape elements of the plot can be superimposed [25, 26].

42.3.2 Indicator Revision, Assignment, and Establishment

Harbin has four distinct seasons and belongs to the severe cold regions of northern China. According to the status quo of high-rise residential areas in Harbin, two expert interviews were conducted, and 30 experts were interviewed, including 11 experts in landscape field, 10 experts in planning field, 2 experts in construction field, 2 real estate practitioners, 1 municipal expert and 4 designers.

The purpose of the first interview was to screen and adjust the Seattle Green Factor Assessment Indicators for the actual situation of high-rise residential areas in Harbin. Subsequently, the questionnaire interview was based on the characteristics of the Harbin cold city, and the scores were assigned to the evaluation indicators. Finally, the Green Space Factor assessment form for high-rise residential areas in Harbin is determined (see Table 42.1).

Table 42.1 Green Space Factor assessment form for high-rise residential areas in Harbin

Landscape type	Landscape elements	Score
Landscaped areas A	A1: Landscaped areas with a soil depth of less than 24 in.	0.2
	A2: Landscaped areas with a soil depth of 24 in. or greater	0.6
	A3: Bioretention facilities	0.9
Plantings B	B1: Mulch, ground covers, or other plants less than 2 in. tall at maturity	0.2
	B2: At maturity, shrubs or perennials are more than 2 ft. high, and each plant is 12 ft^2. (typically not more than 18 ft^2)	0.4
	B3: Small deciduous trees with a crown width of 8–15 ft., calculated as 75 ft^2 per tree	0.4
	B4: Small evergreen arbor crowns are 8–15 ft., calculated as 75 ft^2 per tree	0.4
	B5: Small or medium-sized deciduous trees with a crown width of 16–20 ft., calculated as 150 ft^2 per tree	0.4
	B6: Small or medium-sized evergreen trees with a crown width of 16–20 ft., calculated as 150 ft^2 per tree	0.4
	B7: Medium or large deciduous trees with a crown width of 21–25 ft., calculated as 250 ft^2 per tree	0.5
	B8: Medium or large evergreen trees with a crown width of 21–25 ft., calculated as 250 ft^2 per tree	0.5
	B9: Large deciduous tree with a crown of 26–30 ft., calculated at 350 ft^2 per tree	0.5
	B10: Large evergreen trees with a crown width of 26–30 ft., calculated as 350 ft^2 per tree	0.5
	B11: Large trees with a trunk diameter of 6 in. or more, calculated at 20 ft^2 per inch in diameter	0.8
Permeable pavement C	C1: Pervious pavement on 6–24 in. of soil or gravel	0.2
	C2: Permeable paving over at least 24 in. of soil or gravel	0.4
Water D	D1: Closed water landscape	0.1
	D2: Open water landscape	0.7
Bonuses E	E1: Planting medium height between 2 and 4 in.	0.4
	E2: Planting medium height is above 4 in.	0.6
	E3: Within 5 years into the area covered by vegetation	0.6
	E4: Drought-tolerant or native plant species	0.3
	E5: Meet at least 50% of the area that is irrigated annually by using collected rain or snow water	0.3
	E6: Landscaping visible to passersby from adjacent public right of way or public open spaces	0.1
	E7: Landscaping in food cultivation	0.1

42.4 Result

42.4.1 Analysis Results of High-Rise Residential Areas in Harbin Based on Green Space Factor Assessment

According to the size of the high-rise residential area, nine high-rise residential areas were selected as typical research cases. The typical residential areas selected have different volume ratios, different green rate and cover all evaluation factors as much as possible. The Green Space Factor assessment was carried out for the nine settlements. The higher the Green Space Factor value, the better the ecological benefit of the settlement. The evaluation results are shown in Table 42.2.

42.4.2 Analysis of the Impact of Landscape Elements on Ecological Benefits

It can be seen from the evaluation process of the case settlement that the higher the score of the landscape element indicates the better the ecological benefit of the indicator is. As shown in Fig. 42.1, we can see that the use of any of the following 25 indicators can improve the overall ecological benefits of the settlement, but the ecological benefits provided by different landscape elements are different.

The bioretention facilities (A3) has the highest ecological benefits followed by large trees with a trunk diameter of 6 in. or more (B11) and an open water landscape (D2). The landscaped areas with a soil depth is 24 in. or greater (A2), and planting medium height is above 4 in. (E2) and wall greening (E3) provide high ecological benefits. For the effective improvement of the ecological benefits of settlements, the specific practices are as follows:

In the landscape area, we can see that the bioretention facilities (A3) has the highest weight value, so setting up bioretention facilities can effectively improve ecological benefits. The landscaped areas with a soil depth are of 24 in. or greater scores much higher than landscaped areas with a soil depth of less than 24 in. Therefore, under the condition that the landscape area is limited, increasing the thickness of the soil to 24 in. or more can maximize the ecological benefits of the area.

It can be seen from plant cultivation that different plant planting forms have a great impact on ecological benefits. If stratified planting is followed, that is, arbor–shrub—turf planting, the indicators can be superimposed to improve ecological benefits. Increasing the size of the tree to achieve a crown width of 21 ft. (B7) or more will also improve the ecological benefits. When the trunk diameter of the tree reaches 6 in. or more (B11), the ecological benefit is the highest at this time.

It can be seen from the paving that the ecological benefit of using the area in permeable paving over at least 24 in. of soil or gravel (C2) is the highest when the area of the pavement is limited.

Table 42.2 Table of basic information on case settlements and composition of green space factors

High-rise resident	Floor area (m^2)	Volume ratio	Greening rate (%)	Green Space Factor indicator composition	Score
Kaixuan Square	32,000	2.1	20	A1,A2,B1,B2,B3,B4,E4	0.20
Walk around Paris	185,840	2.25	36.42	A1,A2,B1,B2,B3,B4,B5,B7,B9,C1,C2,D1,E4	0.38
Xidian Home	200,000	2.4	40	A1,A2,B1,B2,B3,B5,B7,B9,C2,D1,E3,E4,E7	0.29
Nanjun, Shannon Jarno Phase I	82,166	2.45	43.36	A1,A2,B1,B2,B3,B4,B5,B6,B7,C1,C2,D1,E4,E6	0.50
Swan Bay	156,107	2.53	40	A1,A2,B1,B2,B3,B4,B5,B6,B7,C1,C2,D1,D2,E4	0.54
Youth City Phase I	61,843	3.33	38	A1,A2,B1,B2,B3,D1,E4	0.27
Zhonghai Huijing Xi'an	97,049	3.7	45	A1,A2,B1,B2,B3,B4,C2,D1,E4	0.53
Yujintai	25,780	4.8	30	A1,A2,B1,B2,B3,B4,B5,B7,C2,D1,E4	0.42
Zijincheng	59,304	5.3	37	A1,A2,B1,B2,B3,B4,B5,C1,C2,E4	0.36

Fig. 42.1 Indicator score distribution table

The open water landscape (D2) scores higher than the closed water landscape (D1), so using the open water landscape as the water landscape can maximize the ecological benefits of the region.

It can be seen from the bonus points that increasing the area of green roof (E2) and wall greening (E3) can effectively improve ecological benefits.

42.4.3 Relationship Between Greening Rate and Ecological Benefits

After the case evaluation, it is found that the advantages and disadvantages of the ecological benefits of the high-rise residential areas are related to the greening rate. Residential areas with low greening rates also have poor ecological benefits. Residential areas with high greening rate have certain advantages in ecological benefits, but not all residential areas with high greening rate have good ecological benefits.

Greening rate is positively related to ecological benefits: As shown in Fig. 42.2a, the greening rate of the Kaixuan Square community is lower than that of other communities, so the ecological benefits of the Kaixuan Square community are also worse than those of other communities. As the greening rate of residential areas increases, the probability of increasing ecological benefits increases. For example, the greening rate of the Youth City Phase I community is lower than that of the Nanjun, Shannon Jarno Phase I community, and the ecological benefits of the Youth City Phase I community are lower than that of the Nanjun, Shannon Jarno Phase I community. Because of its high greening rate, Zhonghai Huijing Xi'an Community is also superior in terms of the advantages and disadvantages of ecological benefits.

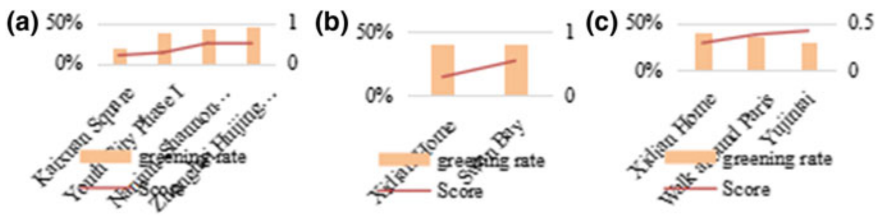

Fig. 42.2 Relationship between greening rate and ecological benefits

Greening rate is not completely related to ecological benefits: As shown in Fig. 42.2b, in Xidian Home Community and Swan Bay Community, although the two communities have the same greening rate, the ecological benefits of the Swan Bay Community are significantly better than the Xidian Home Community.

Greening rate is negatively correlated with the ecological benefits: As shown in Fig. 42.2c, in the Yujintai Community, the Walk around the Paris Community, and the Xidian Home Community, although the greening rate increased, the ecological benefits decreased.

Subsequently, we analyzed the two landscape types with the largest proportion of Xidian Home Community, Walk around Paris Community, Yujintai Community, and Swan Bay Community, namely the landscape area and planting. As can be seen from Figs. 42.3 and 42.4, the greater the proportion of the landscape area occupied by landscaped areas with a soil depth of 24 in. or greater (A2), the higher the ecological benefits of the settlement. The greater the proportion of trees and shrubs planted, the higher the ecological benefits of settlements. Therefore, improving the greening rate of residential areas will help to improve the ecological benefits of settlements. However, improving the ecological benefits of settlements depend not only entirely on improving the greening rate of settlements but also on the allocation of landscape elements. For residential areas with low greening rate, the adjustment of landscape elements such as increasing the number of shrubs can effectively improve the ecological benefits.

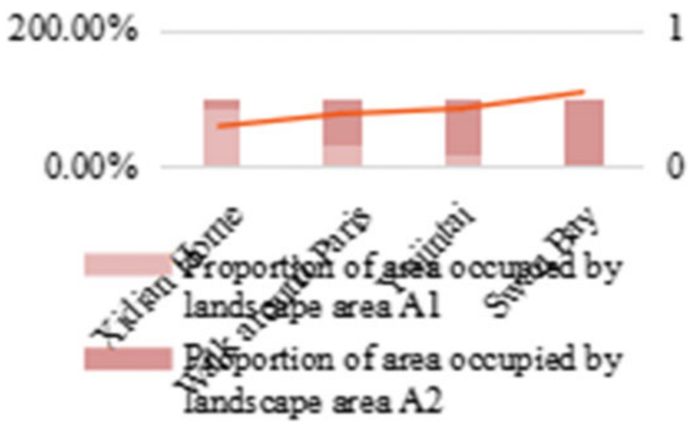

Fig. 42.3 Area ratio of landscape area

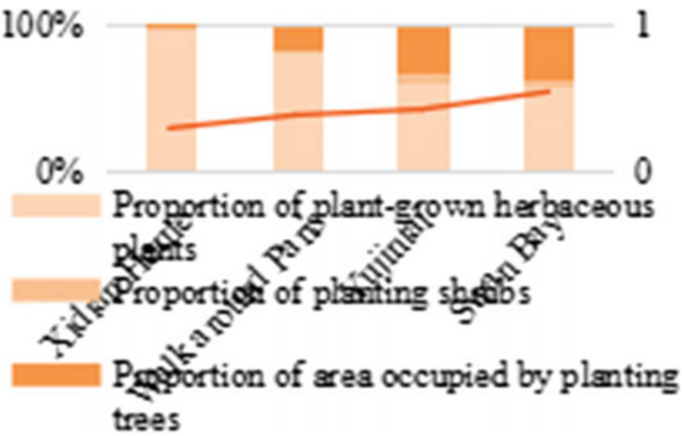

Fig. 42.4 Proportion of plant area

42.4.4 Relationship Between Volume Ratio and Ecological Benefits

It can be seen from the evaluation results that the advantages and disadvantages of ecological benefits are related to the level of volume ratio, as shown below.

The volume ratio is not completely related to the ecological benefits: As shown in Fig. 42.5a, when the volume ratio of the settlement is low, the volume ratio has little effect on the ecological benefits of the settlement. The ecological benefits at this time depend on the greening rate of the settlement and the configuration of the landscape elements.

The volume ratio is negatively correlated with ecological benefits: As shown in Fig. 42.5b, the residential area with a higher volume ratio has less green space to be used, so it is difficult to have a higher greening rate, resulting in a high-volume-ratio residential area that does not dominate the ecological benefits. The high volume ratio of Yujintai Community and Zijincheng Community is the main reason for the poor ecological benefits.

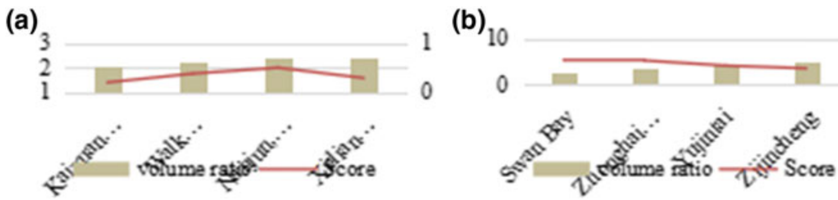

Fig. 42.5 Relationship between volume ratio and ecological benefits

The two landscape types, the landscape area and planting, which accounted for the largest proportion of the Swan Bay Community, Zhonghai Huijing Xi'an Community, Yujintai Community, and Zijincheng Community were then analyzed. As shown in Figs. 42.6 and 42.7, it can be seen that when the volume ratio of the settlement is high, increasing the proportion of the landscape area of the green area with the soil thickness greater than or equal to 24 in., and increasing the proportion of large trees and shrubs planting, etc., can improve the ecological benefits of the settlement area. When the green area of the high volume ratio residential area is limited, increasing vertical greening, such as wall greening, can effectively improve ecological benefits.

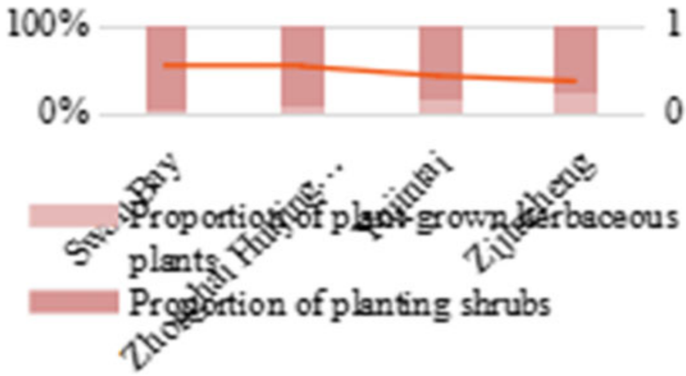

Fig. 42.6 Landscape area ratio

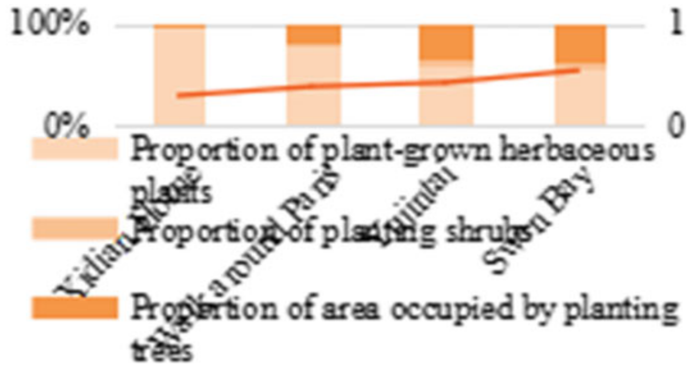

Fig. 42.7 Proportion of the planted area

42.5 Discussion

42.5.1 The Universality of the Green Space Factor Indicators and the Rationality of the Weight Values

Due to the limitations of this study and the number of samples as well as the lack of support for the Harbin native plant database, there is no precise method. In addition, the weight adjustment and setting methods in this paper use the expert method and other methods, which have certain subjectivity. Therefore, some more quantitative and accurate related verification studies are needed to guide the scientific setting of index setting and weight value.

42.5.2 Try to Develop Green Space Factor Indicators for Urban Land Use

In this study, only the Green Space Factor tool is applied to the high-rise residential areas in Harbin. It is suggested that the application level of this type of tool can be extended to provide an urban development center.

42.5.3 Limitations of Green Space Factor Methods

Although the Green Space Factor Assessment Tool provides quantitative criteria for the development of urban green infrastructure, there is no restriction on its design tools, and there is no relevant assessment of the quality of the completed project. Therefore, project managers and project designers are required to conduct relevant processing to achieve the desired esthetic value and ecological service value.

42.6 Conclusions

This study is based on the Seattle Green Factor tool to construct a Green Space Factor tool for Harbin, a cold winter city, to assess the ecological benefits of high-rise residential areas in Harbin. Through the assessment of the ecological benefits of nine case settlements in Harbin, we draw the following conclusions:

The advantages and disadvantages of the ecological benefits of high-rise settlements are directly related to the allocation of landscape elements. The higher the scores of the landscape elements are, the better the ecological benefits are.

The ecological benefits of residential areas with low greening rates are not necessarily poor. For low green areas, the settlement can also achieve high ecological benefits by adjusting the configuration of landscape elements.

As the volume ratio of high-rise residential areas increases, the difficulty of providing better ecological benefits increases. For high-volume-dwelling settlements, high ecological benefits can also be achieved by adjusting the configuration of landscape elements.

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