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Impact of Urban Green Spaces Based on Geographic Information System on Residential Area Prices and Development Strategies: A Case Study of Wuhan City, Hubei Province

Cheng Li, Xiong Li,* Ying Yu, Xinlin Lin, and Di Li

Beijing Forestry University, 35 Qinghua East Road, Haidian District, Beijing 100083, China

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In this study, we utilized the ArcGIS Geographic Information System (ArcGIS) to study the relevant datasets of park green and residential subsidiary green spaces in Wuhan City, and at the same time, scraped residential area prices data in Wuhan using big data technology. The inverse distance weight spatial interpolation method is employed to analyze the spatial patterns of residential area prices. Distances from each residential area to park green spaces at different scales are calculated to investigate their impact on residential area prices. Three strategies are proposed: the tailored allocation of different types of park based on regional characteristics, the implementation of "quantity guarantee and quality improvement" measures to enhance the quality of residential green spaces, and the promotion of interaction between park green and residential green spaces. These strategies aim to particularly uplift housing prices in economically disadvantaged areas, ultimately achieving shared prosperity.

1. Introduction

According to statistics from the People's Bank of China, the main carrier of China's national material wealth is self-owned residential areas, accounting for more than 70% of the total household assets. The disparity in residential area prices largely determines wealth gaps, and apart from factors such as location and quality, the relationship of residential area with urban green spaces also significantly affects residential area prices. Particularly in today's increasingly scarce urban land and compact construction, large-scale urban development makes green space resources increasingly scarce,(1) and the positive externalities and ecological functions of urban green space considerably increase the value of land and affect residential area prices.

Currently, domestic and international research studies in China primarily focus on two aspects. The first is the relationship between park accessibility and residential area prices. Scholars such as Bangjia *et al.* approached this from the perspective of "socially disadvantaged groups," measuring the actual park green space service levels accessible to residents.(2) Second, there is a shift in data acquisition methods from traditional to multisource data acquisition.

*Corresponding author: e-mail: 846243917@qq.com
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Scholars such as Haiwei and Fanhua,[3] Dawei *et al.*,[4] and Ziwei and Hui[5] utilized ArcGIS spatial analysis methods to study the relationship between urban park green spaces and residential space evolution in cities such as Jinan, Nanjing, and Shenzhen. However, there is a lack of research on the relationship between different types and scales of urban green spaces and housing prices. Jun *et al.* studied multisource data such as house prices and remote sensing images and used neighborhood analysis and a geographically weighted regression (GWR) model to analyze green space accessibility and its spatial correlation with house prices in the Zhongshan District of Dalian City.[6]

Ge investigated the factors affecting housing prices in Nanjing on the basis of the GWR model.[7] Wen *et al.* took the completed sheltered housing in Guangzhou City as the research subject and conducted GIS network analysis to evaluate the accessibility of sheltered housing residents to green spaces of different size classes by different transportation modes.[8] However, there is a lack of research on the relationship between the impacts of different types and sizes of urban green spaces on residential area prices.

In this paper, we explore the joint impact of urban park green and residential subsidiary green spaces on residential area prices using GIS technology and the inverse distance weight (IDW) spatial interpolation method. For green spaces, proximity to green spaces of different scales and the greenness rate of residential areas are selected as measurement indicators; for residential spaces, residential area prices are the measurement indicator.[9–14] On the basis of this indicator system, we investigated how urban park green and residential subsidiary green spaces affect residential area prices. Here, we propose development strategy recommendations.

2. Data and Methods

2.1 Study area

The scope of this study focuses on the impact of urban green spaces on residential area prices and the scale differences therein. As the administrative area of Wuhan is delineated in a large area, the peripheral administrative area contains most of the villages and towns that cannot be queried for accurate housing prices, and at the same time, the existence of a large area of mountains and forests is likely to affect the subsequent analysis. Therefore, in this paper, on the basis of the built-up area data for Chinese cities in 2020 extracted by Jie *et al.*, the built-up area of Wuhan is delineated to be approximately 1062 km^2.[15] The research area is selected within the built-up area of Wuhan (see Fig. 1 for the boundary of Wuhan's built-up area), including park green spaces, residential areas, and their associated green spaces, as the study objects.

2.2 Datasets

2.2.1 Residential area (data source, main content, and processing)

Geospatial data for the residential area includes the name of residential areas, land area, green coverage rate, residential plot ratio, and so forth. Python code programming is used to

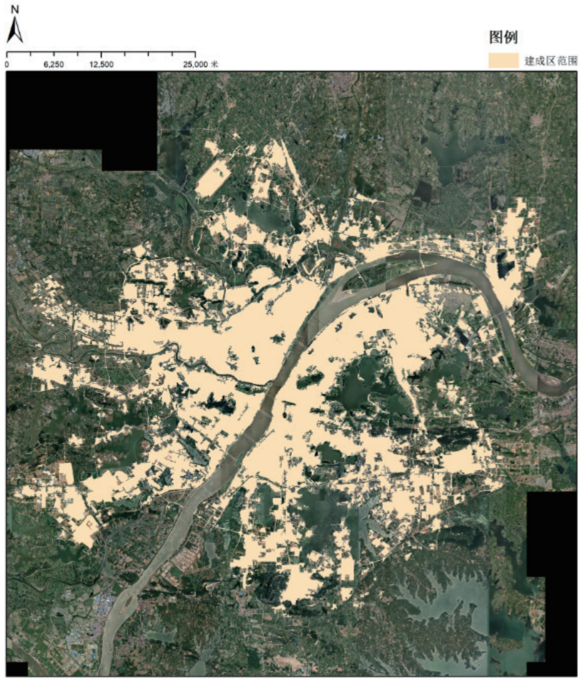


Fig. 1. (Color online) Built-up area boundary of Wuhan City.

collect residential area prices from the Anjuke website to ensure the authenticity, effectiveness, and comparability of the overall data. Finally, ArcGIS is utilized to establish a spatial database for data analysis. The distribution of residential areas in Wuhan is shown in Fig. 2.

2.2.2 Public parks

Geospatial data for parks is extracted from the 2020 satellite remote sensing image of the built-up area of Wuhan City. This involves tasks such as data registration, map vectorization, and verification. In combination with standards such as "Classification and Planning Standards for Urban Land Use (GB50137-2011)" and "Classification Standards for Urban Green Spaces (CJJT85-2017)", park green spaces are selected and a spatial database for park green spaces is established. The distribution map of public parks in Wuhan is shown in Fig. 3.

2.3 Methods

First, the spatial pattern of residential area prices is analyzed by the IDW spatial interpolation method.[16] Then, using ArcGIS, the distances from each residential area to public parks are calculated for both overall parkland and different scales of parkland. Finally, SPSS is utilized to explore the correlations among parkland proximity, greenness rate, and residential area prices.

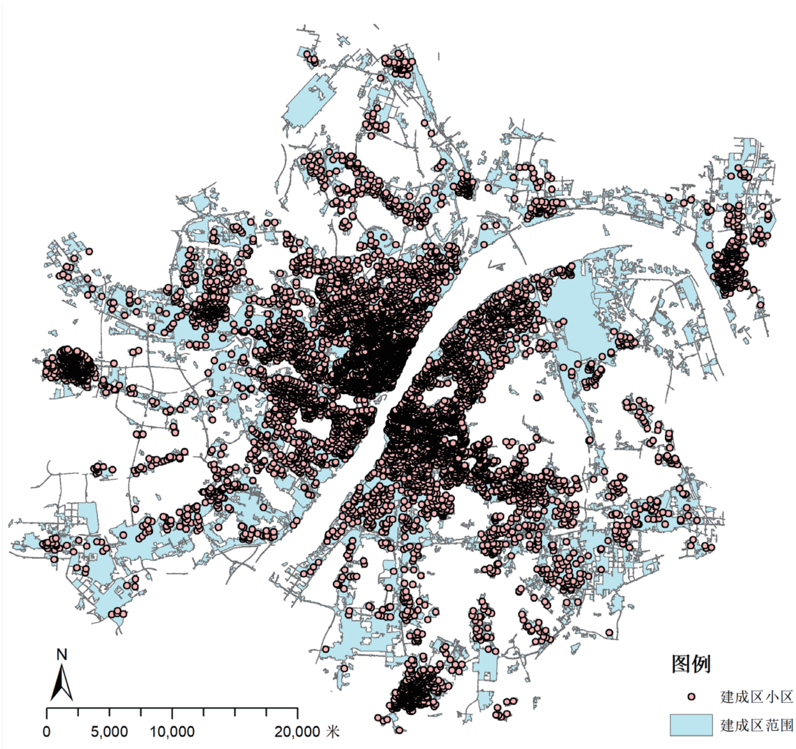


Fig. 2. (Color online) Residential area distribution map.

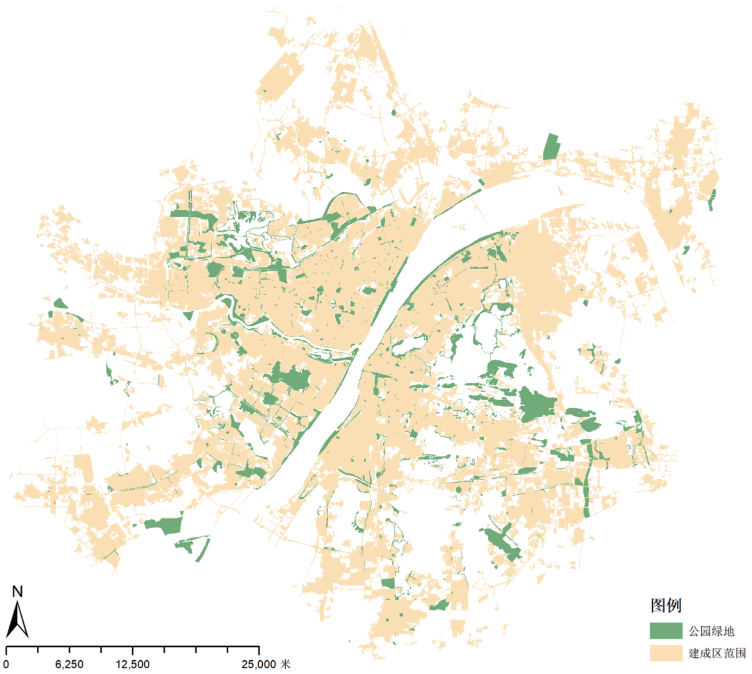


Fig. 3. (Color online) Distribution map of park green spaces.

3. Results and Analysis

3.1 Patterns of spatial variation in residential area prices

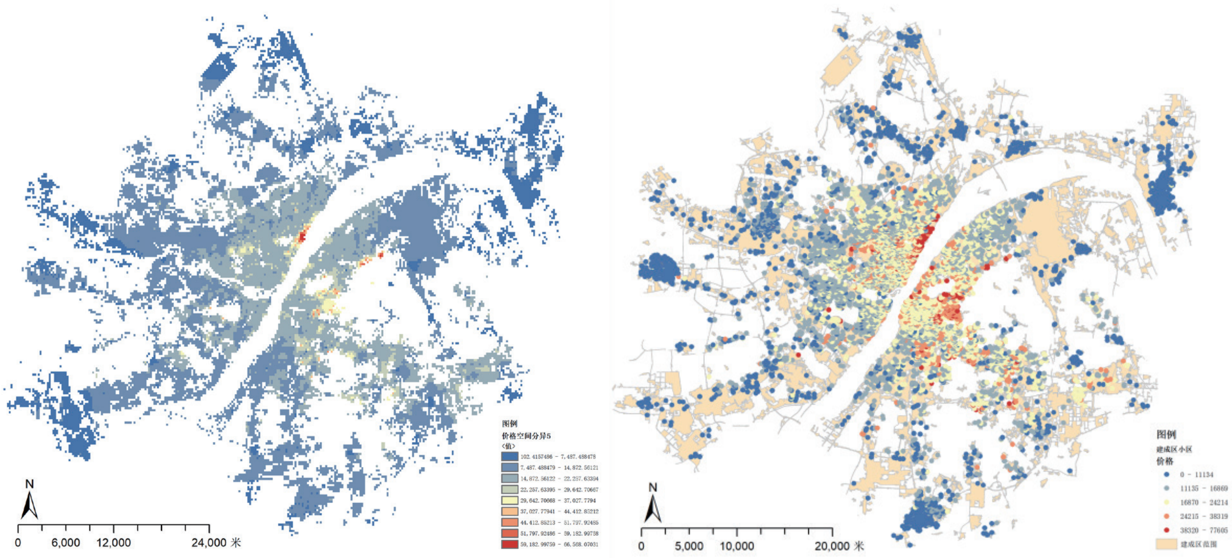
There are 9914 residential area prices in the built-up area of Wuhan, which are mainly distributed along two rivers and beside the landscape system in the built-up area, with an average selling price of RMB 17007.97/m^2.

IDW spatial interpolation is based on the first law of geography — the similarity of regions close to each other is higher than that of regions far from each other, and the disadvantage of this interpolation method is that it cannot estimate the error. The IDW value can be expressed as

$$Z = \sum_{i=1}^{n} \frac{Z}{d_i^p} l \sum_{i=1}^{n} \frac{l}{d_i^p}, \tag{1}$$

where Z is the estimated value, Z_i is the ith (i = 1, ..., n) sample, d_i is the distance, and p is the power of the distance, which significantly affects the results of the interpolation, and it is selected using the criterion of the minimum mean absolute error.

The results (e.g., Fig. 4) are as follows: most of residential area prices are distributed between 10000 and 30000 RMB/m^2; the overall trend is polyconcentric, decreasing from the three cities of Wuhan's old urban area to the periphery and spreading in all directions from the East Lake area and the area of the intersection of the two rivers. The peak prices are distributed in the East Lake area and the area of the intersection of the two rivers. The high-value zones are clustered along the northwest–southeast direction, mainly distributed in the northwest–southwest direction.

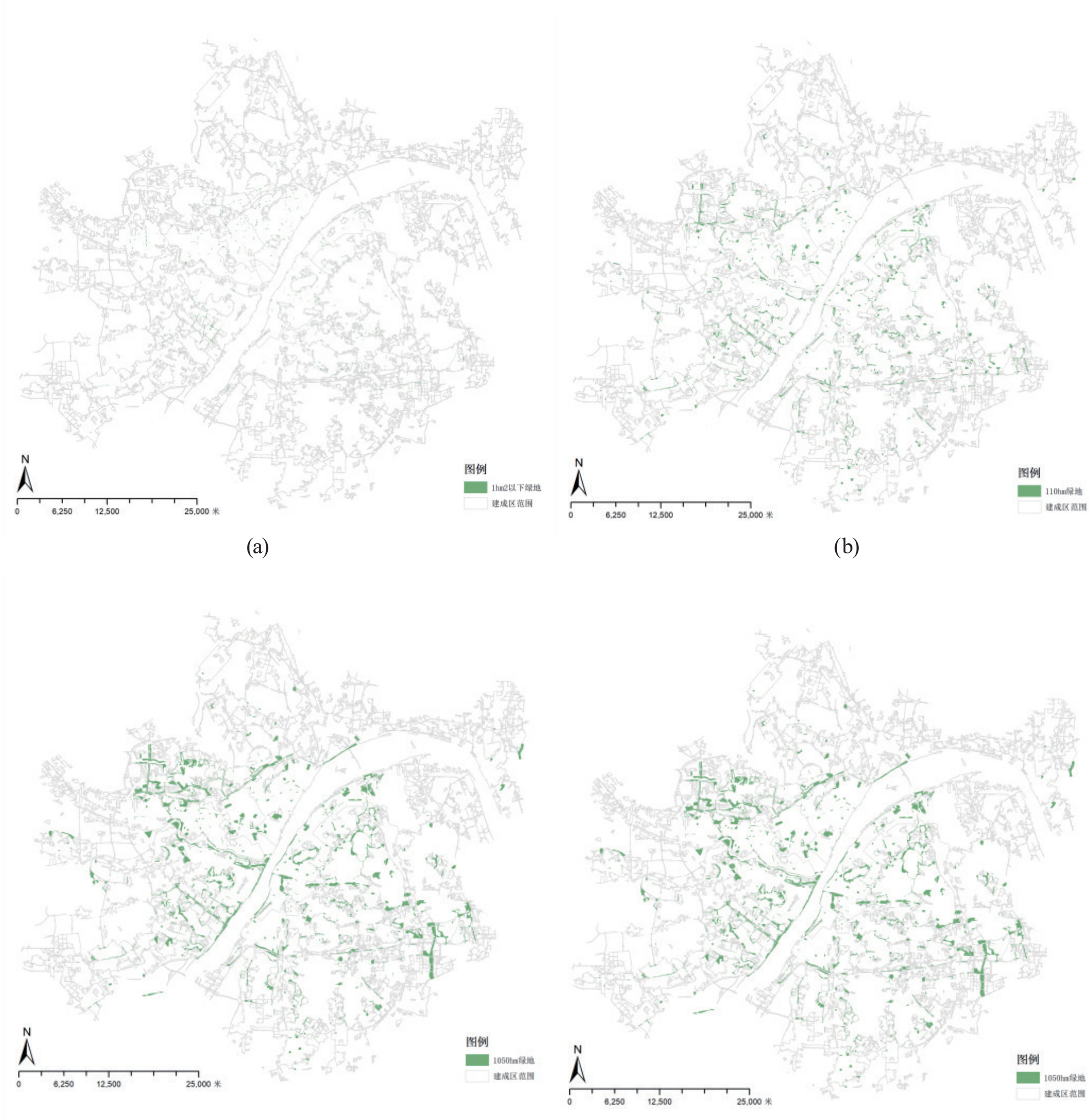


(a) (b)

Fig. 4. (Color online) Patterns of spatial variation in residential area prices: (a) analysis of the IDW spatial interpolation method for housing prices and (b) housing price point distribution.

3.2 Analysis of distribution of public parks at different hierarchical levels

As of 2020, the completed park green spaces in the study area reached 1478 places, with a total area of 7282 ha, an increase of 1055 ha or 16.94% from 2015, showing a rapid expansion trend. In reference to the Specification for Landscape Projects and the Urban Green Space Classification Standard, the park green spaces are divided into four scale levels, namely, less than 0–1 hm², 1–10 hm², 10–50 hm², and more than 50 hm², in order to analyze the relationship between the proximity level of the green spaces and the price distribution of the residential area prices. The park green spaces were categorized into the above scales for the level analysis (e.g., Fig. 5).



(a) (b)

(c) (d)

Fig. 5. (Color online) Distribution of park green spaces at different scales: (a) 0–1 hm² of park green spaces, (b) 1–10 hm² of park green spaces, (c) 10–50 hm² of park green spaces, and (d) more than 50 hm² of park green spaces.

3.3 Impact of proximity to park green spaces on residential area prices

3.3.1 Analysis of overall proximity levels of park green spaces

In this paper, the level of spatial proximity between the residential area and parks is measured using the distance from the residential area prices to the edge of the nearest public parks by the minimum distance method, and the results are categorized into five grades according to the natural break-point method, namely, “very good”, “good”, “fair”, “poor”, and “very poor”. Figure 6 shows that the distribution of green parks in Wuhan as a whole is reasonable, and the proximity of parks in housing estates near the northern edge of the built-up area is poor.

From Figs. 7(a)–7(l), it can be seen that residential area prices with high proximity levels are mainly concentrated in Jianghan, Jiangan, Qiaokou, Hanyang, and Wuchang districts, with a concentrated distribution of public parks and housing estates, and a high degree of convenience of services, whereas Caidian, Huangpi, and Xinzhou districts, as new districts, have a lower level of overall proximity to parks, and the distribution of housing is also less.

3.3.2 Analysis of proximity levels of park green spaces at different scales

On the basis of scale difference characteristics, from Figs. 8(a)–8(d), it can be seen that the housing estates with a higher proximity level of public parks with an area of 0–1 hm² are concentrated in Jiangan District, Jianghan District, and Wuchang District, and the proximity level of Hongshan District is basically worse; the housing estates with a higher proximity level of public parks with an area of 1–10 hm² are mainly located in Jiangan District, and the other areas are basically converging; the proximity levels of public parks with areas of 10–50 hm², 50 hm², and more than 50 hm² are basically converging, and the housing estates with a higher proximity

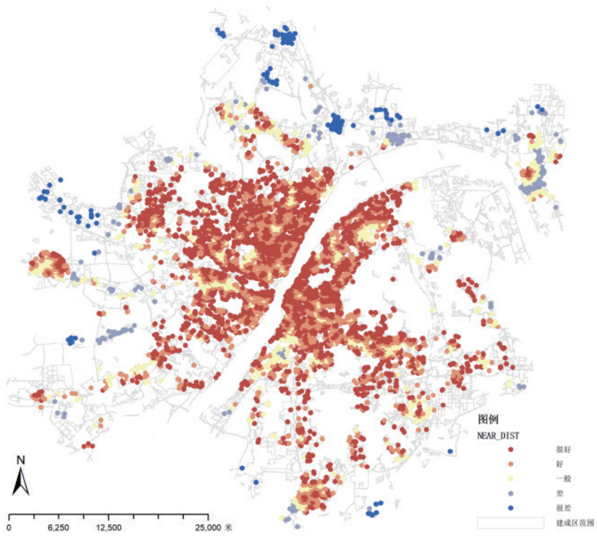


Fig. 6. (Color online) Spatial proximity rating of residential area prices to overall park green spaces.

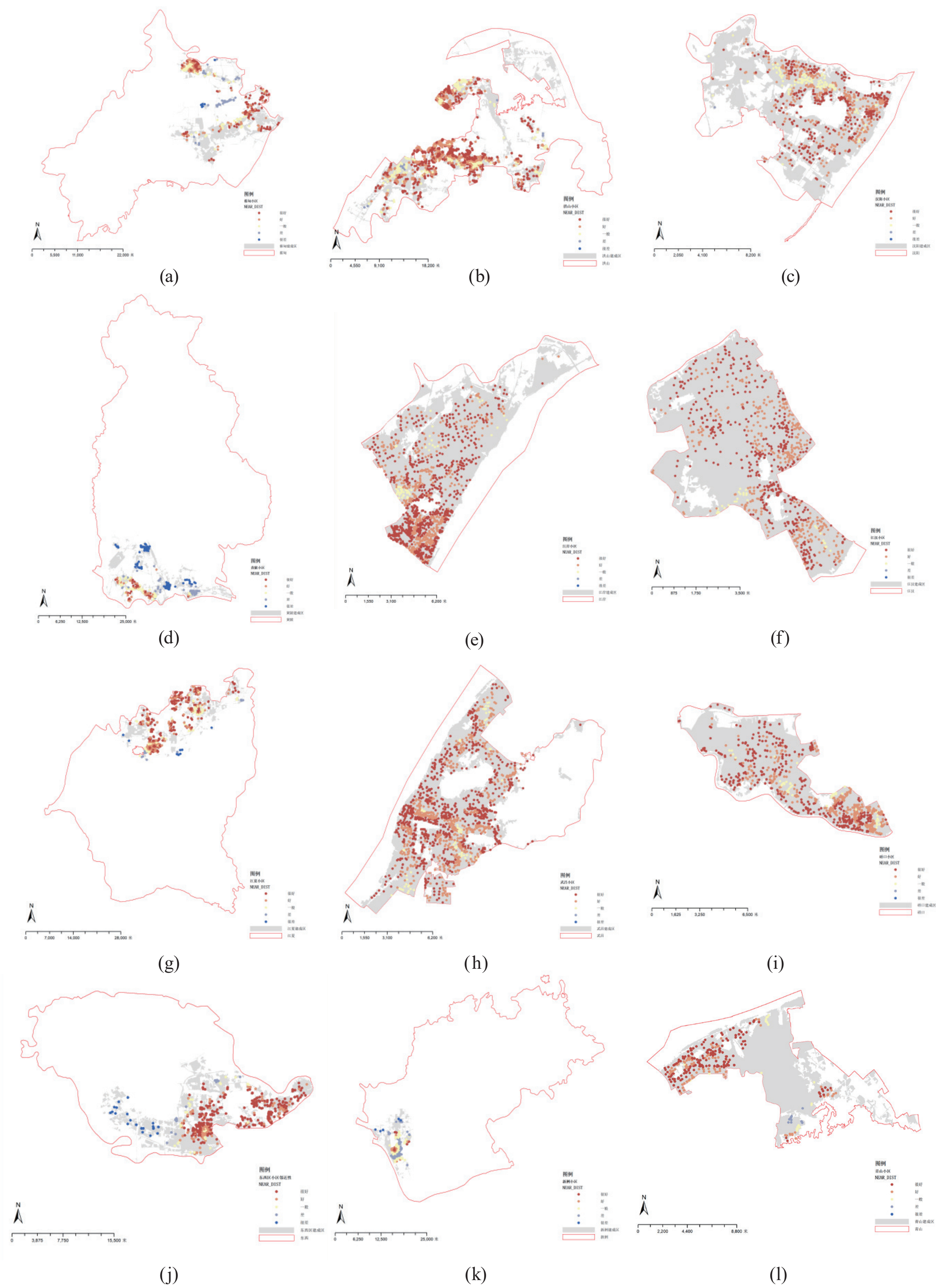


Fig. 7. (Color online) Spatial proximity rating of residential area prices to overall public parks in each administrative district: (a) Caidian District, (b) Hongshan District, (c) Hanyang District, (d) Huangpi District, (e) Jiangan District, (f) Jianghan District, (g) Jiangxia District, (h) Wuchang District, (i) Qiaokou District, (j) East and West Lake District, (k) Xinzhou District, and (l) Qingshan District.

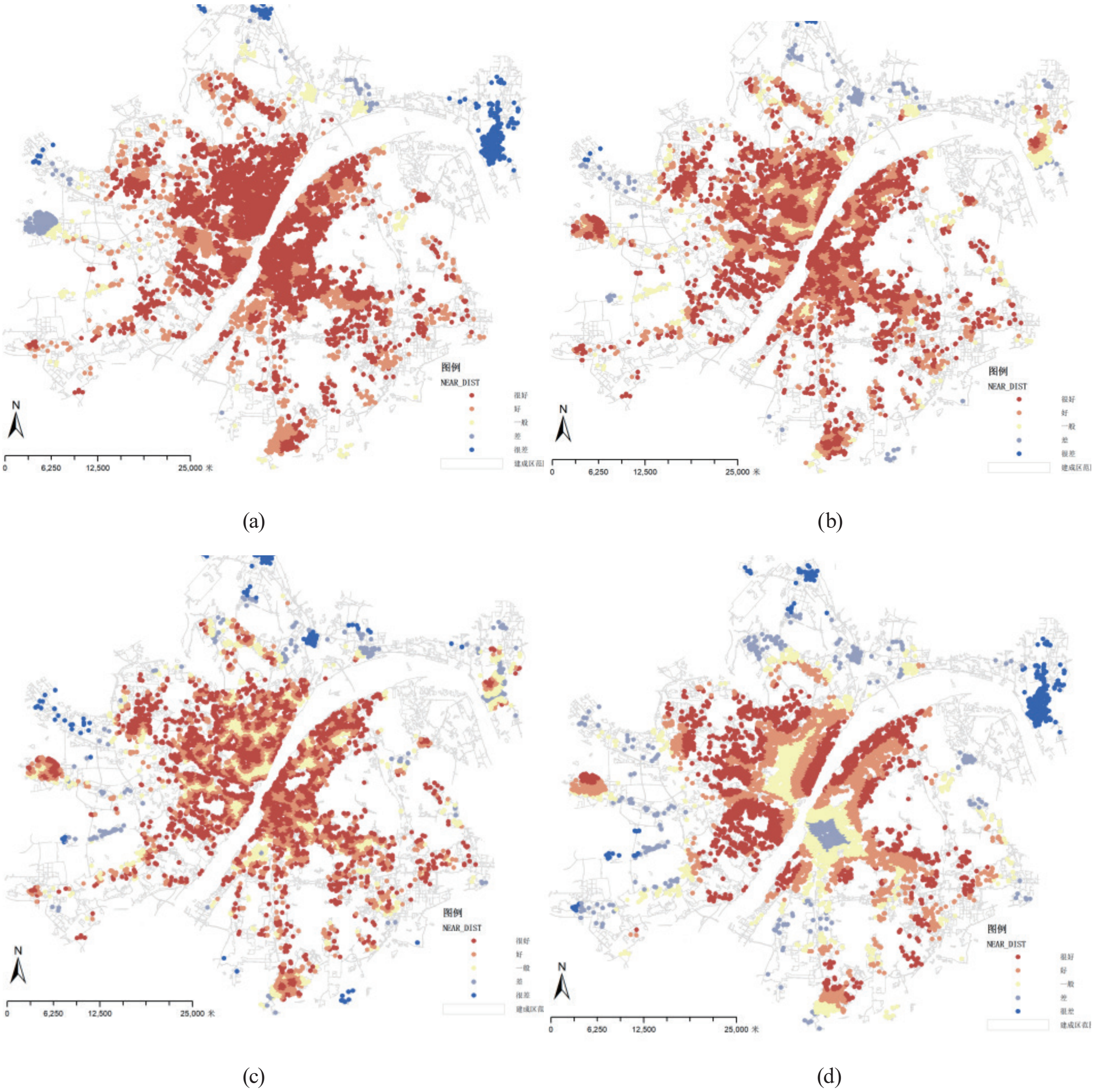
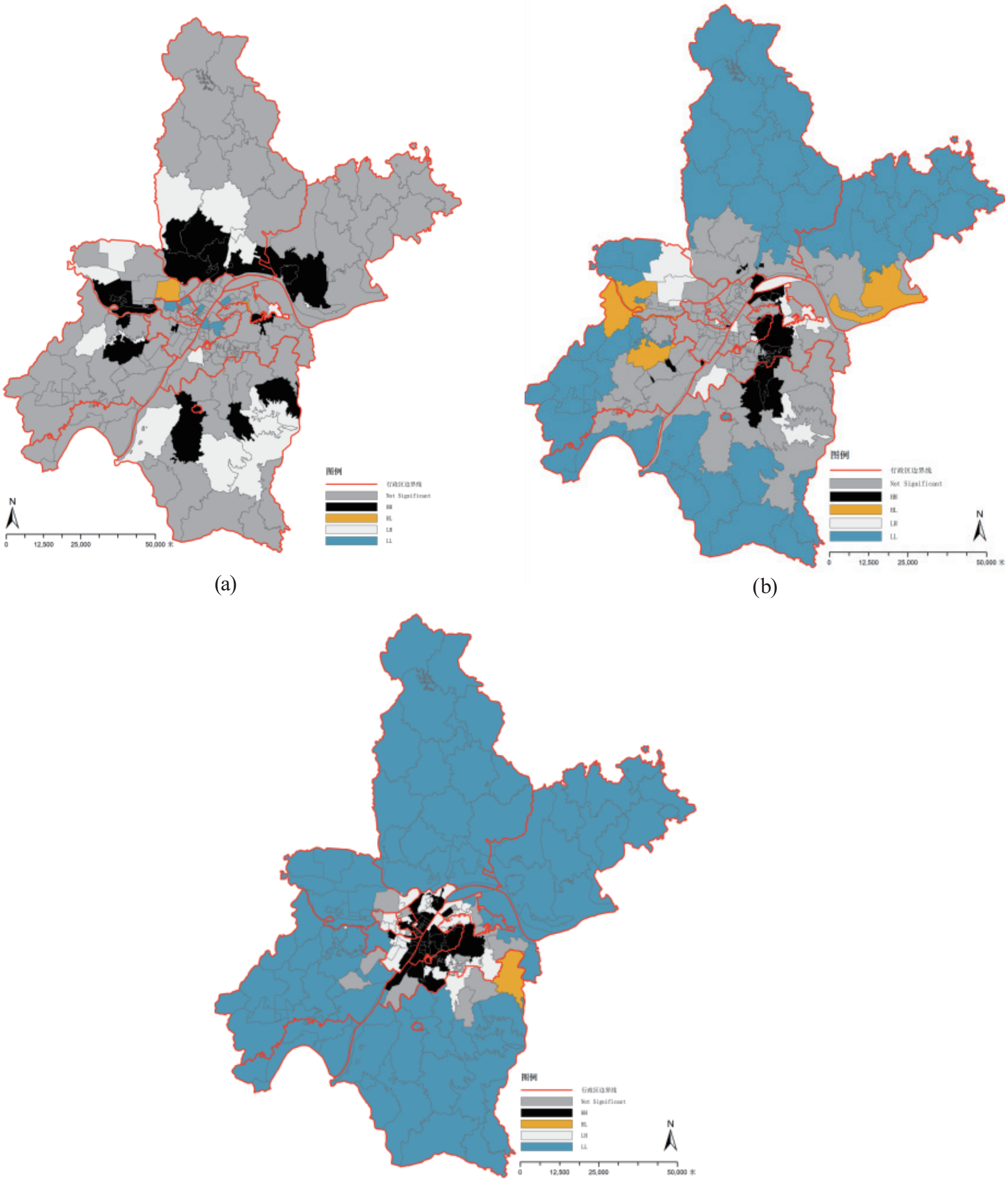


Fig. 8. (Color online) Spatial proximity ratings of residential area prices to park green spaces at different scales: (a) 0–1 hm^2 of park green spaces, (b) 1–10 hm^2 of park green spaces, (c) 10–50 hm^2 of park green spaces, and (d) more than 50 hm^2 of park green spaces.

level are concentrated in Jiangan District, Jianghan District, and Wuchang District. The overall distribution is not significantly different, decreasing from the center to the periphery of Wuhan's built-up area, and has a clustering effect.

3.4 Cluster analysis of values

The hot spots, cold spots, and spatial outliers with crowding significance are identified using ArcGIS infraclustering and outlier analysis, and the weighted elements are analyzed using the Anselin Local Moran's I statistic. Global spatial autocorrelation focuses on representing the spatial aggregation state and the degree of correlation, whereas local spatial autocorrelation can identify the spatial hotspot area, which is an effective indicator for detecting the spatial features and patterns.(17,18) According to the size of the value, the regional units are classified into four types, namely, high-high, low-low, high-low, and low-high. The first two types represent the local spatial aggregation values of high and low values, and the last two represent the local spatial distributions.(19,20) As shown in Figs. 9(a)–9(c), the proximity of park green spaces is relatively good in new districts such as Huangpi, East and West Lake, Caidian, Xinzhou, and Jiangxia Districts, whereas that of park green spaces is poor in Wuchang, Qiaokou, and



(a) (b)

(c)

Fig. 9. (Color online) Cluster analysis of values: (a) cluster analysis of park green space proximity, (b) cluster analysis of greenness rate, and (c) cluster analysis of residential area prices.

Jiangshan Districts within the old urban areas. In terms of the greenness rate indicator, the greenness rate is relatively high in the eastern part of Jiangxia District and in the area near Donghu Lake and Townsend Lake Wetland Park in Hongshan District, and the greenness rate of housing on the eastern bank of the Yangtze River is higher than that on the western bank. In terms of the clustering analysis of residential area prices, the residential area prices in Wuchang District, Qiaokou District, and the old urban areas near the Yangtze River in Jiangan District are significantly higher than that in the high-house-price area.

3.5 Analysis of the correlation between park green spaces and residential area prices

3.5.1 Overall correlation analysis

The greenness rate of residential area was chosen as an indicator to assess the proximity level of green space in residential area, and its correlation with residential area prices and the proximity of park green spaces was examined. As shown in Table 1, park green spaces are generally significantly and negatively correlated with the proximity of park green spaces, i.e., the closer housing estates are to park green spaces, the higher their price. The greenness rate of residential areas is significantly and positively correlated with their prices, i.e., the higher the greenness rate of residential areas, the higher their price, and there is no significant correlation between the proximity of park green spaces and the greenness rate of residential areas.

3.5.2 Correlation analysis of park green spaces at different scales

Park green spaces are categorized into four scales, namely, 0–1 hm² or less, 1–10 hm², 10–50 hm², and 50 hm² or more, and the parks are screened according to their distances of 100 m, 300 m, 500 m, and 1 km from residential areas. The correlations between the proximity of residential areas to the neighboring parks of different scales and the three indicators of greenness rate and residential area prices are studied.

According to the correlation analysis (e.g., Table 2), when there is a park green space with an area of 10–50 hm² within 500 m, there is a significant positive correlation between the residential area prices and the greenness rate of residential areas. When there is a park green space with an area of more than 50 hm² within 1 km, there is a significant positive correlation between the greenness rate of park green space and the proximity to the park green space.

Table 1
Overall correlation analysis.

		Greenness rate of residential areas	Residential area prices	Proximity level of park green spaces
Greenness rate of residential areas	Correlation coefficient	1		
Residential area prices	Correlation coefficient	0.065^{**}	1	
Proximity level of park green spaces	Correlation coefficient	−0.015	-0.292^{**}	1

Note: **Correlations are significant at the 0.01 level (two-tailed).

Table 2
Analysis of the correlation between parks of different sizes and green spaces in housing estates.

Area of park			Greenness rate of residential areas	Residential area prices	Proximity level of park green spaces
0–1 hm²	Greenness rate of residential areas	Correlation coefficient	1		
	Residential area prices		0.032	1	
	Proximity level of park green spaces		−0.009	−0.005	1
1–10 hm²	Greenness rate of residential areas	Correlation coefficient	1		
	Residential area prices		0.018	1	
	Proximity level of park green spaces		0.000	−0.019	1
10–50 hm²	Greenness rate of residential areas	Correlation coefficient	1		
	Residential area prices		0.041**	1	
	Proximity level of park green spaces		−0.017	−0.025	1
More than 50 hm²	Greenness rate of residential areas	Correlation coefficient	1		
	Residential area prices		0.019	1	
	Proximity level of park green spaces		−0.055*	−0.048	1

Note: *Correlations are significant at the 0.05 level (two-tailed).

4. Synergistic Development Strategy of Urban Green Space and Residential Area under the Perspective of Common Wealth

4.1 Configuration of different types of park according to regional characteristics and local conditions

Hanyang, Jiangan, Qiaokou, and Wuchang Districts in the old urban areas of Wuhan are high-density construction areas, which can promote the development of small and microparks and green spaces in synergy with residential areas, and the construction of parks and green spaces of less than 1 ha. Moreover, as new urban areas such as Huangpi, Caidian, and Xinzhou Districts are not yet fully constructed, there is more space to add large park green spaces of more than 50 ha, which can significantly enhance the value of residential areas.

4.2 Adoption of “quantity and quality” measures for the improvement of quality of public parks in housing

The lack of a clear relationship between the greenness rate of residential areas and residential area price indicators shows that the amount of green space is not the key to the residential area prices. For this reason, measures have been taken to improve the quality of park green spaces within residential areas by emphasizing the improvement of the quality and functionality of living for residents in order to satisfy the residents' quest for a high-quality green environment and to increase the value of residential areas.

4.3 Promoting interaction between public parks and residential green spaces

By enhancing connectivity between green spaces, especially between parks and residential green spaces, public parks will become an important driving force to stimulate the vitality of the region and promote the optimization of the functional space of the city, so as to deepen the connection between public parks and residential areas.

5. Conclusions

In this study, we investigated the relationship between urban green spaces and residential area prices using ArcGIS technology. We have reached the following conclusions:

1. Overall, there is a significant correlation among the following indicators: residential area greenness rate, residential area prices, and proximity to parks.
2. There is no significant correlation between proximity to surrounding parks (excluding parks with areas of more than 50 hm^2) and the residential area greenness rate and residential area prices.

On the basis of these conclusions, we propose the following development strategies:

1. Tailor the allocation of different types of park based on regional characteristics.
2. Implement "quantity guarantee and quality improvement" measures to enhance the quality of residential green spaces.
3. Promote interaction between park green spaces and residential green spaces to enhance the value of residential areas, especially in areas with lower prices.

In the future, it is essential to focus on research areas such as improving the quality of green spaces within residential areas and exploring the impact, strategies, and mechanisms of other types of green space on residential area prices.

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About the Authors

Cheng Li received his B.S. and M.S. degrees from Beijing Forest University, China, in 2011 and 2014, respectively. From 2014 to 2021, he was an assistant research fellow in the Urban-Rural Planning Administration Center, Ministry of Housing and Urban Rural Development. Since 2021, he has been pursuing a doctoral degree in landscape architecture at Beijing Forestry University. His research focuses on landscape greening technology management.

Xiong Li received his B.S., MS., and Ph.D. degrees from Beijing Forestry University, China, in 1985, 1988, and 2006, respectively. From 2007 to 2016, he was the Dean of the School of Landscape Architecture and Professor of Beijing Forestry University, China. Since 2016, he has been the Vice President and Professor of Beijing Forestry University, China. His research interest is in landscape architecture planning and design.(lixiong@bjfu.edu.cn)

Ying Yu is currently an undergraduate student in urban and rural planning at Beijing Forestry University, where she is in her fifth year. Her research focuses on data-driven urban studies, exploring innovative pathways and methodologies for urban development by integrating data analysis with urban planning theories.

Xinlin Lin is currently a fifth year undergraduate student at Beijing Forestry University, majoring in urban and rural planning. Her research focuses on urban regeneration through the preservation and inheritance of historical and cultural heritage in urban regeneration.

Di Li is currently a doctoral student at the University of California, Berkeley, majoring in landscape architecture and environmental planning. His research focuses on the evolution of the relationship between cities and water in China since the early modern period.