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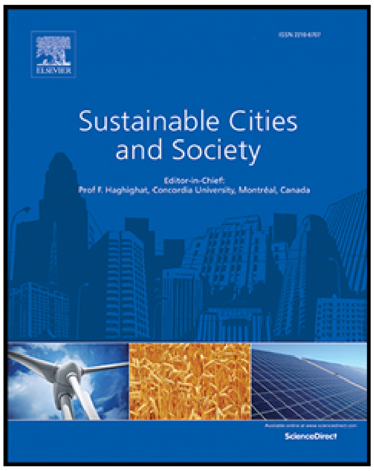

Identifying Spatial Mismatches between the Supply and Demand of Recreation Services for Sustainable Urban River Management: A Case Study of Jinjiang River in Chengdu, China

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Identifying Spatial Mismatches between the Supply and Demand of Recreation Services for Sustainable Urban River Management: A Case Study of Jinjiang River in Chengdu, China

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Highlights:

- We propose a comprehensive framework for supply-demand analysis of urban river recreation.
- A case study in Jinjiang River illustrates how the framework can support urban river management.
- The clear supply-demand mismatches of urban river recreation service in Jinjiang River are found.
- Potential factors are road density, residential community density, and distance to the city center.
- The service supply should be improved based on the population and distribution of the demand.

Abstract

Urban river recreation services (URRS) are very important for improving the quality of urban life. Understanding the balance between the supply and demand of URRS can facilitate sustainable urban river management. First, we analyzed the spatial patterns of the URRS supply and demand in Jinjiang River. We then identified spatial mismatches from three dimensions (river recreation spaces, residential communities, and the service region) by using the Gaussian two-step floating catchment area (2SFCA) method. Finally, we revealed the main influencing factors and their interactions. The results showed that: (1) the URRS supply gradually increased from upstream to downstream; (2) the URRS demand in the midstream was the strongest, followed by the downstream and upstream; (3) the supply-demand mismatches were severe, with 50.29% of the URRS region in short supply; and (4) the main influencing factors included distance to the city center, supply of river recreation spaces, and riverfront distance. Road density, residential community density, and distance to the city center could enhance the impact of other factors. Our research can improve the quantity and distribution of urban riverfront green spaces, as well as provide a reference for urban residential layout or planning.

Keywords

Urban ecosystem; Ecosystem services; Residential communities; Interactive influence; 2SFCA

1. Introduction

Urban rivers, as one of the most important urban ecological corridors (Peng et al., 2017), supply diverse and critical ecosystem services, including provisioning, regulating, cultural, recreational, and aesthetic services (Hua and Chen, 2019). Among them, the importance of recreation services to citizens' quality of life and well-being has recently received increased recognition (Komossa et al., 2020; Wang et al., 2020). Urban rivers link citizens to nature through the river landscape (Durán et al., 2021), and urban riverfront open spaces are the main recreational areas for urban riverfront residents. Urban river recreation services (URRS) mainly include the appreciation of aesthetically pleasing landscapes (Liu et al., 2021) and opportunities for riverfront recreational activities, such as recreational running, walking, leisure boating, and swimming (Durán et al., 2021).

The URRS supply is defined as the potential of urban rivers to provide recreation services, without consideration of actual human recognition or use of the services (Liu et al., 2020). The URRS demand depends on the level of social and economic development (Peng et al., 2017), especially the recreational needs of riverfront residents. The URRS supply-demand mismatches refer to the imbalance between the supply of urban rivers and the demand of residents. If the supply is less than the demand, it will lead to social injustice and decrease the well-being of the unsatisfied demand groups, and thus stimulate claims on policy makers or other actions; if the supply is greater than the demand, it will cause a waste of resources on the supply side (Lorilla et al., 2019).

The URRS supply-demand matches are very important to urban river management. Currently, the ecological restoration of urban rivers is mainly focused on improving the river quality and riverfront environment (Guimarães et al., 2021), without considering the spatial matching relationship between supply and demand. As a result, the planning of urban riverfront open spaces is insufficient. Identifying spatial mismatches between the supply and demand of URRS can be used to effectively plan urban riverfront open spaces (Liu et al., 2020), and to increase recreational opportunities.

Current research on the matching relationship between the supply and demand of urban ecosystem services has mainly focused on urban green spaces (Liu et al., 2020), parks (Liu et al., 2021), brownfields (Washbourne et al., 2020), land use change (González et al., 2020), and urbanizing watersheds (Meng et al., 2020). The supply and demand of urban green spaces or parks recreation services is an important content of current research, including the supply and demand assessment (Liu et al., 2020), the supply-demand spatial patterns (Liu et al., 2021), and the quantification of supply-demand mismatches (Ma, 2020; Xing et al., 2018).

Common methods to quantify the supply-demand mismatches include calculating the supply-demand ratio within a pre-defined region (Potestio et al., 2009; Wang et al., 2020), and evaluating the spatial autocorrelation of supply and demand. For example, Chen et al. (2019) and Liu et al. (2020) quantified the supply-demand ratio on a regional or sub-district scale, while Meng et al. (2020) assessed the spatial matching between supply and demand through spatial autocorrelation analysis. All of these studies concentrated primarily on a whole region, failing to clarify the supply-demand mismatches from the service supplier and demander. Although the two-step floating catchment area method (2SFCA) (Xing et al., 2020) is widely used to quantify the spatial accessibility of urban green spaces, it is also suitable to evaluate the matching relationship between supply and demand. The 2SFCA comprehensively considers the supply scale, the demand scale, and the service overlap region in the calculation (Wang et al., 2020). Therefore, this method considers the spatial relationship between supply and demand, and it is more accurate than the calculation of the supply-demand ratio within a whole region. Combining the Gaussian 2SFCA (Hu et al., 2020) and the Kriging spatial interpolation method (Zhang et al., 2015), we propose to identify URRS supply-demand mismatches from three dimensions of the service supplier, the service demander, and the service region. This method can facilitate the optimization of supply-side, demand-side, and help to provide regional suggestions.

The common influencing factors of the matching between the supply and demand of urban recreation services are location (Bing et al., 2021), population (Wang et al., 2020), socio-economic status (Dai, 2011; Wilkerson et al., 2018), the distribution of ecological recreation spaces (Zhou and Wang, 2011; Wang et al., 2020), urbanization (Meng et al., 2020), and relevant policies (Wei, 2017). Studies on these factors are based on qualitative or descriptive statistical analysis and mainly discuss the individual influence intensity of each factor. However, the spatial difference of supply-demand matching is a comprehensive reflection of the interaction of various social, economic, and environmental factors. For example, urban economic development usually increases the road density, which in turn increases the chance of entering urban green spaces for recreation (Chen et al., 2020). However, the more urbanized areas, the more limited green space available for recreation (Xie et al., 2018), which reduces the potential for recreational supply (Meng et al., 2020; González et al., 2020). Therefore, it is worth considering whether the interaction between these influencing factors enhances or weakens the individual influence intensity of each factor.

This study aims to develop a comprehensive analysis framework for identifying the spatial mismatches of the URRS supply and demand. The Jinjiang River is used as an example. The specific objectives are to: (a) describe the spatial patterns of the URRS supply and demand; (b) identify the URRS supply-demand mismatches from three dimensions: the service supplier, the service demander, and the service region; and (c) detect the main influencing factors of the URRS supply-demand mismatches, and reveal the interaction between influencing factors. Our study can help to optimize urban riverfront recreation spaces, and provide guidance for urban residents to use riverfront recreation services.

2. Materials and methods

2.1. Study area

Jinjiang River is called the "Mother River" by Chengdu people, and related historical records on this river date to 2,300 years ago. The Jinjiang River (also known as Funan River) is the collective name of Fuhe River and Nanhe River. Fuhe River starts at Tuanjie Township, Pixian County and ends at Jiangkou Town, Pengshan County, with a total length of 97.3 km. Nanhe River starts at Songxian Bridge and ends at Hejiang Pavilion, with a total length of 5.63 km. The mainstream of Jinjiang River was selected as study area (Fig. 1 a), which is 44.27 km in length and flows through seven urban districts (Fig. 1 b). The riverfront environment of the upstream, midstream, and downstream are different (Fig. 1 c). The upstream of the study region is located in rural areas, the midstream in established urban areas, and downstream in new urban areas. The riverfront environment in the midstream is better developed, and the riverfront parks are more densely distributed. These regional differences are suitable for studying the spatial mismatches of the URRS supply and demand.

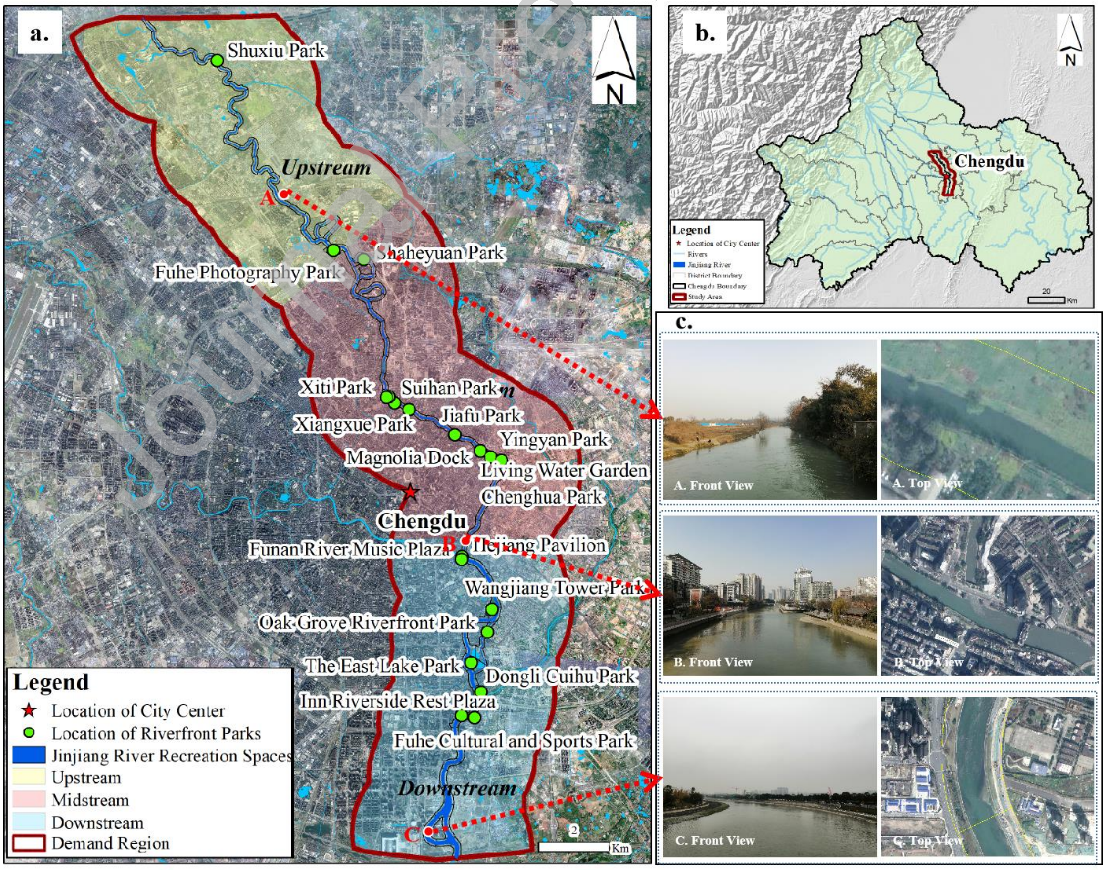

Fig. 1. Location of the study region (a. Regional scope of the URRS supply and demand; b. The location of Jinjiang River in Chengdu; c. Front/top view of different river recreation spaces.)

2.2. Data

We used high-resolution Google Earth images (1.07-m resolution), Ovi map and field surveys to map the Jinjiang River and its riverfront green spaces, parks, and roads. By using Python, we obtained the name, number of households, housing prices, geographic coordinates, and 4640 residential communities in the study area from Lianjia (https://cd.lianjia.com/xiaoqu/), Shell (https://cd.ke.com/xiaoqu/), Soufang (https://cd.sofang.com/rentesb/area), and Baidu map (https://map.baidu.com/@11589061,3566692,13z). According to the 2019 Chengdu Statistical Yearbook (http://www.cdstats.chengdu.gov.cn/htm/detail_179930. html), the average population per household in Chengdu is 2.62. There were differences among districts, and so we estimated the total population of each residential community based on the average household population in the district where the community was located. Finally, a unified spatial projection coordinate system was adopted for all spatial data collected, and the pixel size of the interpolated raster data was fixed at 100 m × 100 m to ensure data compatibility.

2.3. Method

Inspired by the existing researches on the assessment, spatial patterns, and the supply-demand matching, this study supplemented the analysis of the multi-dimensional approach and influencing factor interaction. The framework proposed in this study is schematized in Fig. 2. We first referred to the relevant research on river corridors and urban rivers to determine the boundary of the URRS supply and demand. Secondly, we analyzed the spatial patterns of the URRS supply and demand. The URRS supply was comprehensively reflected by the acreages and qualities of the river recreation spaces. The quality index was the average value of the acreage of these three indicators (river surface, riverfront green spaces or parks, and riverfront walking paths) after normalization. The URRS demand was evaluated using the population of residential communities within the demand region. We then identified the spatial mismatches between the URRS supply and demand from three dimensions: the service supplier, the service demander, and the service region. Finally, the main influencing factors and the interaction between these factors were detected.

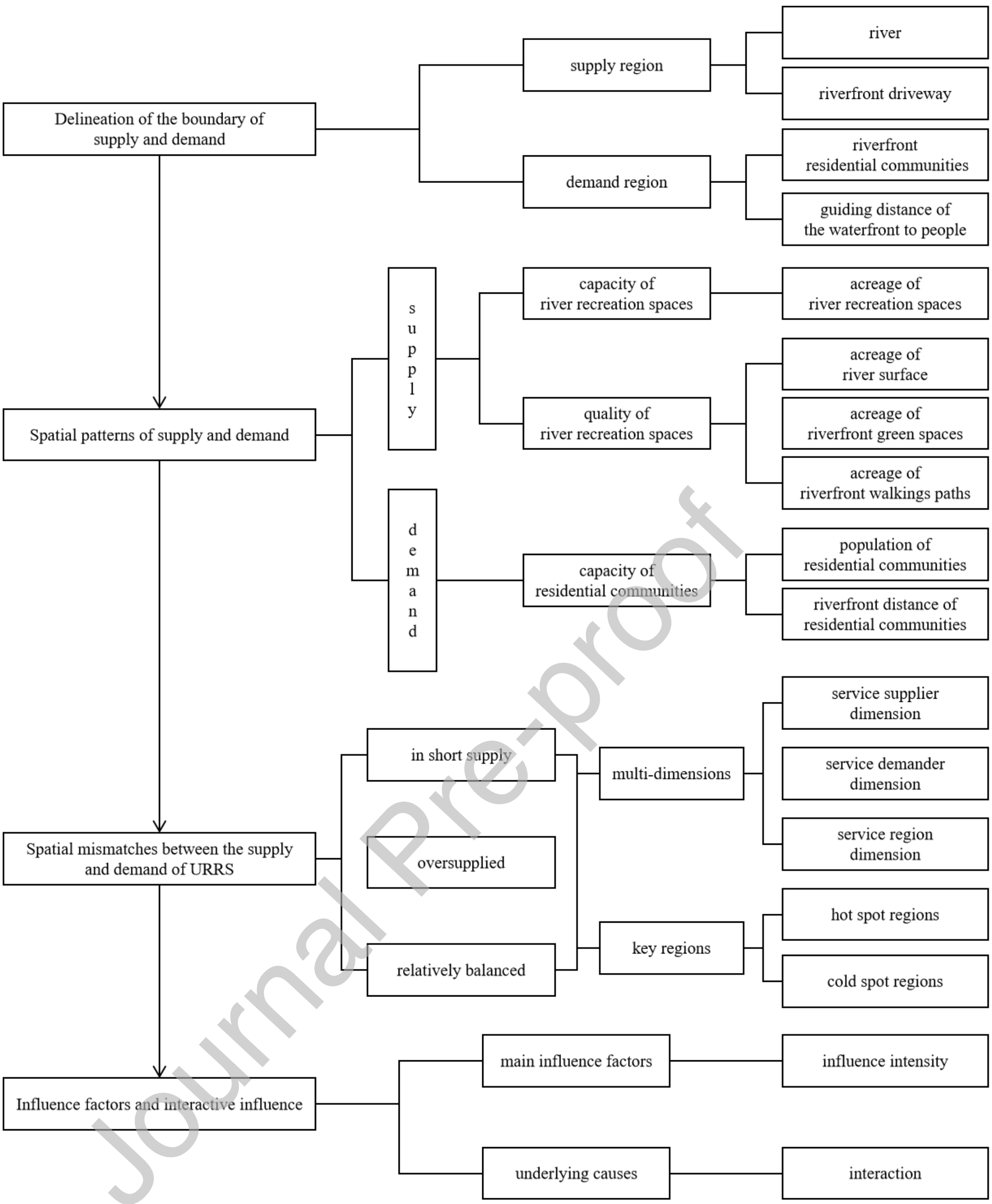

Fig. 2. Research framework for identifying the URRS supply-demand mismatches.

2.3.1. Delineation of the boundary of supply and demand

Based on the concept of ecological corridors in landscape ecology, river corridors refer to the vegetation zone that includes the river itself and the vegetation distributed along the river and that differs from the surrounding substrate (Yue et al., 2005). For different research purposes, a variety of methods have been proposed to delineate the riverfront buffer width. For instance, Dosskey et al. (2002) used an empirical value method to delineate riverfront buffer width as 9–35 m for the purpose of protecting water quality; Meleason and Quinn (2004) analyzed the effective regulation of the riparian forest buffer on microclimate and delineated the riparian buffer width as 5–30 m; Kinley et al. (1997) aimed to protect rare birds in the riparian zone and believed that the riverfront buffer width should be at least 50 m; and Bachiller et al. (2019) was interested in the shading efficiency of riverfront vegetation and delineated the riverfront buffer width as 50 m.

The urban river corridor is a belt-shaped space, and Little (1990) believed that a city river is essentially a greenway. Refer to existing riverfront buffer widths and riverfront recreation activity spaces, we delineated the region between the urban river and the nearest driveway along the river as the URRS supply region, excluding driveways. In addition, we defined a supply region as a river recreation space, including the river, riverfront green spaces, parks, riverfront walking paths, and other riverfront land use, with an average riverfront buffer width of 50 m (Fig. 3a). For riverfront green spaces and parks, the URRS supply region was subjected to the coverage of riverfront green spaces and parks (Fig. 3b).

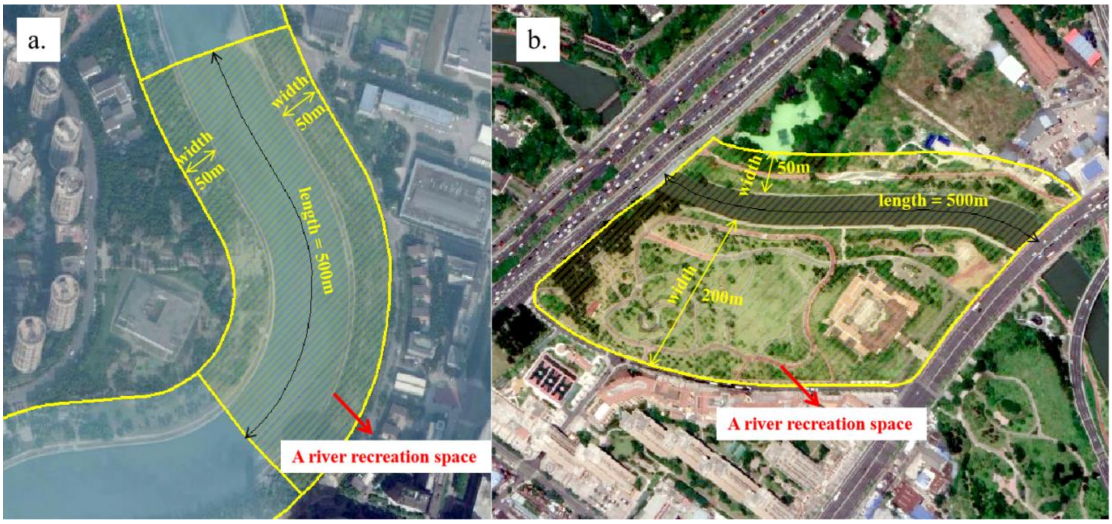

Fig. 3. The boundary of a river recreation space (a. Without riverfront parks; b. with riverfront parks)

According to the guiding distance of the waterfront to people (Othman et al., 2021), a good water and land environment could be a distance of 1–2 km, which is approximately equal to a walking distance of 15–30 min. Therefore, we delineated the URRS demand region as the area within 2 km on both sides of the river. Since we mainly analyzed the URRS utilization by urban residents, the demand population was mainly focused on the resident population of residential communities within this range, without considering the recreational demand of the migrant population.

2.3.2. Supply estimation method

Combined with the characteristics of different river recreation spaces, including river width and riverfront green space distribution, we divided the Jinjiang River into 88 river recreation spaces. Each river recreation space was regarded as a URRS supply region, with a length of 500 m and a riverfront bank width of 50 m (Fig. 3 a). The URRS supply was comprehensively reflected by the acreage and quality of the river recreation space (Wang et al., 2020). The quality of a river recreation space was a key indicator for evaluating the supply (Xing et al., 2020); this relied on the visitation characteristics of residents. Our field investigation found that most residents visited river recreation spaces for relaxing, social interactions, running, walking, leisure boating, or swimming. Thus, our study selected these three indicators to evaluate the quality of river recreation spaces: the acreage of river surfaces (reflecting the probability of recreation in the river), the acreage of riverfront green spaces or parks (with better greening or recreational facilities) (Liu et al., 2021), and the acreage of riverfront walking paths (reflecting the probability of exercise) (Xing et al., 2020). These three indicators were considered equally important to evaluate the URRS supply (Bing et al., 2021). The quality index was the average value of the acreage of these three indicators after normalization. The capacity of the river recreation space was vital for calculating the supply and was determined by its acreage. The specific formulas are as follows:

$$S_j = C_j \times Q_j, \quad ①$$

$$Q_j = 1/3 \times \left(Q_{jr} + Q_{jl} + Q_{jp}\right), \quad ②$$

$$Q_{jx} = (h_x - h_{\min})/(h_{\max} - h_{\min}), \quad ③$$

$$S_j^{'} = \begin{cases} S_j, & 0 \le d \le \frac{1}{3} d_{\max} \\ \frac{2}{3} S_j, & \frac{1}{3} d_{\max} < d < \frac{2}{3} d_{\max} \\ \frac{1}{3} S_j, & \frac{2}{3} d_{\max} < \mathrm{d} < d_{\max} \end{cases}, \quad ④$$

where S_j is the URRS supply of the river recreation space j; C_j is the capacity of the river recreation space j, which is calculated by the acreage of the river recreation space; Q_j is the quality index of the river recreation space j; Q_{jr} is the quality value calculated by the acreage of the river surface in the river recreation space j; Q_{jl} is the quality value calculated by the acreage of riverfront green spaces or parks in the river recreation space j; and Q_{jp} is the quality value calculated by the acreage of riverfront walking paths in the river recreation space j. We then normalized each quality value to (0, 1) according to formula ③. In formula ③, h_x is the original value before normalization; $h_{\min}$ is the minimum value of the original value; and $h_{\max}$ is the maximum value of the original value. To deliver the supply of the river recreation space j to residential communities and visualize its spatial differences, a service radius delivery method (Liu et al., 2021) was used to quantify the S_j value to residential communities. $S_j^{'}$ is the supply value of a location at a distance of d ($0 \leqslant d \leqslant d_{\max}$) from the river recreation space j. In our research, $d_{\max}$ =2 km.

2.3.3. Method for identifying mismatches between supply and demand

By introducing the attenuation law of recreational activities with distance (Wang et al., 2020), we chose the 2SFCA to evaluate the URRS supply-demand matches. The 2SFCA method (Tao et al., 2020; Xing et al., 2020) takes into account factors such as supply scale, demand scale, service radius, and service-area overlap; therefore, the resulting calculation is more accurate, and it is the latest method for evaluating the matches between the supply and demand of urban recreation services (Wang et al., 2020; Zhang et al., 2021).

While the final results produced by the 2SFCA were only assigned to each residential community, in order to obtain the URRS supply-demand matches of any location within the study area, we needed to estimate the locations outside the residential communities to obtain the spatial difference of the matching. There are many local spatial interpolation methods, including inverse distance weighted interpolation, thin plate spline interpolation, and nearest-neighbor interpolation (Wei et al., 2014). Among them, the Kriging spatial interpolation method (Zhang et al., 2015), also known as the spatial auto-covariance optimal interpolation method, is widely used in fields including groundwater simulation (Belkhiri et al., 2020) and urban air quality evaluation (Beauchamp et al., 2018). When considering the spatial position relationship between the sample point to be estimated and the adjacent known sample point, as well as the spatial autocorrelation of the known sample points, this method maximizes the use of various data provided by spatial sampling. Since the population distribution has a degree of spatial autocorrelation (Wei et al., 2014), it is reasonable to use the Kriging spatial interpolation method to evaluate the URRS accessibility for the population of residential communities. The specific formulae are as follows.

(1) Calculate the match between the supply and demand of each river recreation space (j):

$$R_j = S_j \Big/ \left(\sum_{k \in [d_{kj} \le d_0]} P_k f\left(d_{kj}\right) \mathrm{Pr}ob_{kj} \right). \quad ⑤$$

(2) Calculate the match between the supply and demand of each community (i):

$$A_i = \sum_{q \in [d_{iq} \le d_0]} \mathrm{Pr}ob_{iq} f(d_{iq}) R_q , \quad ⑥$$

$$f(d_{ij}) = \left(\exp\left(-0.5\times\left(d_{ij}/d_0\right)^2\right)-\exp\left(-0.5\right)\right)\Big/\left(1-\exp\left(-0.5\right)\right), d_{ij}\le d_0\ ,$$

⑦

$$\Pr ob_{ij} = S_j f(d_{ij})\Big/\sum_{q\in[d_{iq}\le d_0]} S_q f(d_{iq})\ .$$

⑧

(3) Calculate the match between the supply and demand of the service region:

$$\hat{Z}(A_o) = \sum_{i=1}^{N}\lambda_i Z(A_i),$$

⑨

$$\sum_{i=1}^{N}\lambda_i\gamma\left(A_i, A_g\right)+\mu = \gamma\left(A_i, A_o\right), \sum_{i=1}^{N}\lambda_i = 1\ .$$

⑩

In the formulae, R_j is the matching value between the supply of the river recreation space (j) and the total population of the residential communities within the search radius, which represents the per capita riverfront green area of the river recreation space (j) (m^2/person); k represents all the residential communities within the search radius d_0 to the river recreation space (j); P_k is the number of permanent residents, which represents the scale of the URRS demand by all of the population in a residential community (k); S_j is the supply of river recreation space (j); A_i is the matching of each residential community (i), which represents the per capita riverfront recreation area of the residential community; q represents all river recreation spaces within the search radius d_0 to the residential community (i); $f(d_{ij})$ is the distance attenuation function between the residential community (i) and river recreation space (j); $\Pr ob_{ij}$ is the selection probability of the residential community (i) to the river recreation space (j); $Z(A_i)$ represents the known values, i=1, 2, 3......, n;

$\hat{Z}(A_i)$ represents the unknown values, which are obtained by the linear combination of the known values $Z(A_i)$ of the surrounding sampling points (n); λ_i is the weight of the sampling point, which needs to meet the condition of formula ⑩; $\gamma(A_i, A_g)$ is the semi-variation value between the known value A_i and A_g ; $\gamma(A_i, A_o)$ is the semi-variation value between the known value A_i and the unknown value A_o ; and μ is the Lagrangian multiplier related to the minimization of variance.

After we obtained the URRS supply-demand matching values from these three dimensions (river recreation spaces, residential communities, and the service region), we used the natural breakpoint method (Wei et al., 2014) to classify these supply-demand matching values to visualize the spatial differences. The natural breakpoint method can maximize the gap between groups and optimize the similarity value within groups, which can maximize the objectivity of the classification.

2.3.4. Hot spot analysis

The Getis-OrdGi* index (Liu et al., 2020) is mainly used to detect the local spatial autocorrelation of spatial points, evaluate the degree of aggregation of points at the local spatial level, and identify statistically significant spatial aggregation. We used this index to determine whether there was a significant spatial autocorrelation of the URRS supply-demand matches, and to identify which regions (river recreation spaces, residential communities, and the service region) exhibited the URRS supply-demand mismatches.

The cold spot was the region where demand was significantly higher than supply, while the hot spot was the region where supply was significantly higher than demand.

Cold and hot spots with confidence levels above 95% were considered key regions of supply-demand mismatches (Lorilla et al., 2019). Specifically, the cold spot regions were defined as "regions in short supply," the hot spot regions were defined as an "oversupplied regions," and the regions without significant aggregation were identified as "relatively balanced regions."

2.3.5. Kernel density estimation method

The kernel density analysis method (Mo et al., 2017) is a widely used non-parametric estimation method in spatial analysis. Its principle is to calculate the ratio of the total number of elements in the circle to the whole circular area, by taking the sample point as the center and the pre-defined threshold radius as the circle, so as to obtain the density. We estimated the residential community density based on the kernel density of points and estimated the road density based on the kernel density of lines, both of which were mainly used as the influencing factors for subsequent analysis.

2.3.6. Method for analyzing the influencing factors

The Geodetector (Wang et al., 2010) is an effective tool for detecting spatial differentiation, as it has a fast calculation speed, low data requirements, and high accuracy, and overcomes the limitations of statistical methods for processing variables. Compared with other methods, such as linear regression and principle component analysis, the Geodetector method has better explanatory power for influencing factors of spatial differentiation (Wang and Xu, 2017). The Geodetector is widely applied to the field of land use (Ju et al., 2016), environmental change (Zhang et al., 2021), and risk assessment (Wang et al., 2018). The Geodetector include four detectors: risk detector, factor detector, ecological detector, and interactive detector. They are used to detect the main driving factors that affect the distribution and differences in geographic elements (Wang and Xu, 2017). In our research, the factor detector was used to detect the influence intensity of each factor on the spatial difference of the URRS supply-demand matches, so as to identify the main influencing factors. The interactive detector was used to detect whether the interaction between two influencing factors would increase or decrease their influence on the spatial difference of the URRS supply-demand matches.

Spatial mismatches between the URRS supply and demand are affected by a combination of various factors. Policy strategies, surrounding land use, and socio-economic factors were selected to explore the correlations. First, we selected six indicators (supply of river recreation spaces, residential community density, road density, riverfront distance, distance to the city center, and housing prices) to explore the underlying causes of the spatial mismatches between the URRS supply and demand. The supply of river recreation spaces reflects the URRS supply. The residential community density, namely the population density, significantly increases the demand for ecosystem services (Liu et al., 2020; Wang et al., 2020). Road density can simultaneously act as a facilitator (making the supply more accessible to a wider population) (Xing et al., 2020) and as a barrier (making the supply less accessible to nearby communities by compromising pedestrian accessibility). Riverfront distance of the residential community weakens the URRS supply it captures (Liu et al., 2021).

Distance to city center can be a proxy indicator of more riverfront parks, because of the representative and symbolic value of the center. Housing prices can be used to reflect the living environment of residential communities. Generally, areas with higher housing prices have more convenient transportation and more urban green spaces. Xing et al. (2020) proved that communities with high housing prices enjoyed high access to urban green spaces. We then generated a grid map of 100 m × 100 m in the study area and extracted the supply-demand matching ratio (Y value) of each grid center point and the data of each impact factor (X value). Finally, we used the Geodetector to detect the influence intensity of each factor and the interactive influence of different factors.

3. Results

3.1. Spatial patterns of URRS supply and demand

3.1.1. URRS supply

The average area of the 88 river recreation spaces was 0.08 km^2 and the maximum area was 0.15 km^2. River recreation spaces in the midstream and downstream of Jinjiang were relatively large (Fig. 4a). The URRS supply increased gradually from upstream to downstream (Fig. 4c), and the average URRS supplies in the upstream, midstream, and downstream were 0.61×10^4, 1.74×10^4, and 3.77×10^4 m^2, respectively. River recreation spaces located in the downstream had a wider river surface because of the confluence of other rivers. The closer the river recreation space to the city center, the denser the riverfront green spaces, parks, and roads, and with a better accessibility of the river recreation space.

3.1.2. URRS demand

A total of 4,640 residential communities were the URRS demand points in our research. Residential communities located in the midstream were comparatively greater and more densely distributed (Fig. 4b). The URRS demand in the midstream was the largest (Fig. 4d), and the average demands of the upstream, midstream, and downstream were 0.54×10^4, 4.72×10^4, and 2.96×10^4 persons, respectively. There was no significant difference between the population of each residential community and its riverfront distance, but the population of each residential community was related to the distribution of riverfront parks. In general, the residential communities near riverfront parks had a relatively large population and were more densely distributed.

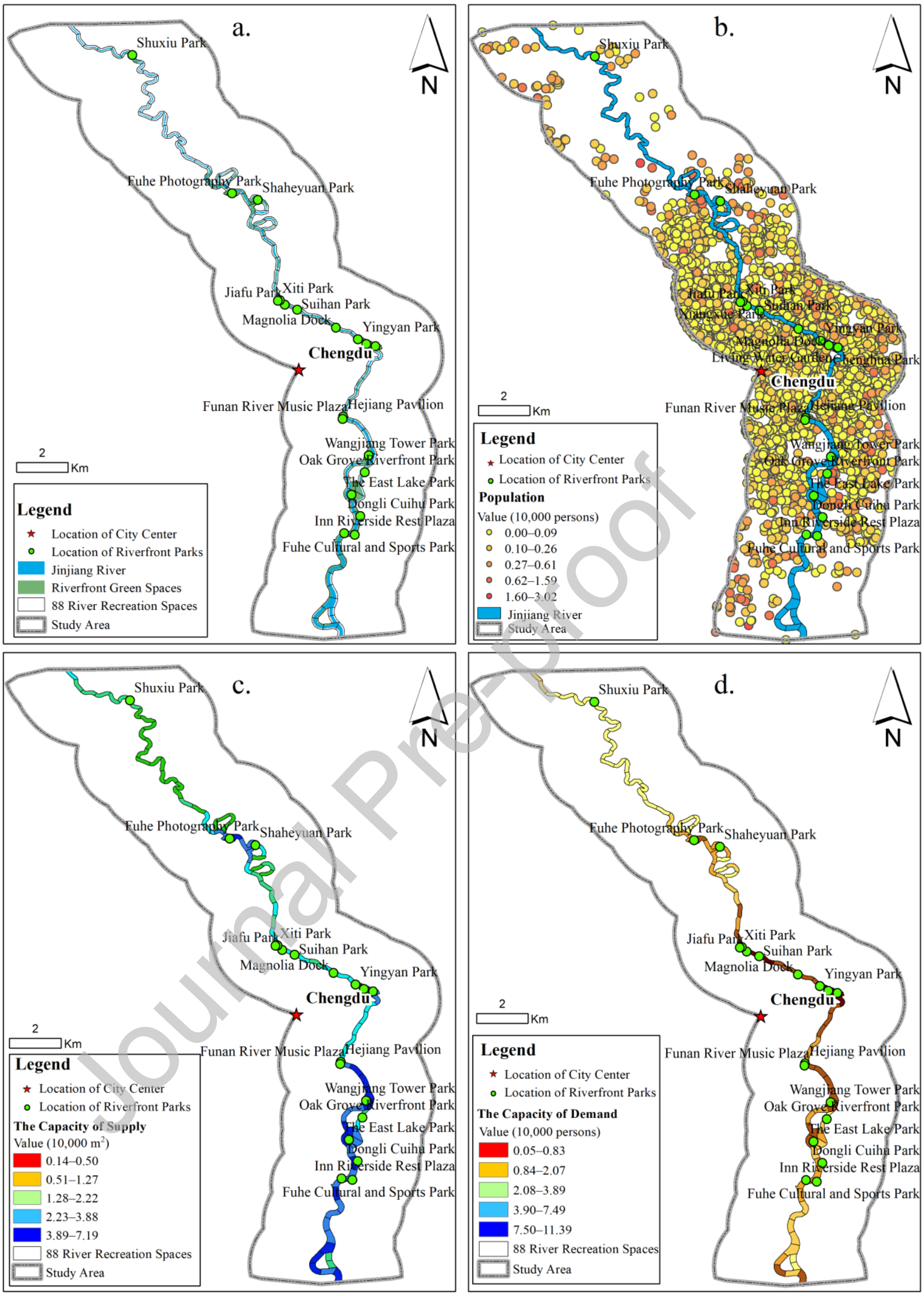

Fig. 4. Spatial patterns of the supply and demand of urban river recreation services (URRS) (a. Spatial distribution of riverfront green spaces. b. Spatial distribution of

residential communities. c. Spatial distribution of the URRS supply. d. Spatial distribution of the URRS demand.)

3.2. Spatial mismatches between the URRS supply and demand

3.2.1. Spatial mismatches between the supply and demand of river recreation spaces

The supply-demand matching value of river recreation spaces in the midstream was the smallest and that in the downstream was the largest (Fig. 5a), and 27.27% of the river recreation spaces were identified as the URRS supply-demand mismatches. Among these spaces, 54.17% were in short supply and 45.83% were oversupplied (Fig. 5d). The average supply-demand matching values of river recreation spaces identified as "in short supply," "balanced," and "oversupplied" were 0.33, 1.08, and 3.04 m^2/person, respectively. The river recreation spaces identified as "in short supply" were mainly located in the midstream near riverfront parks. Although riverfront parks in the midstream were densely distributed, almost all were small parks, and the URRS demand was excessive due to the large population of the residential communities.

3.2.2. Spatial mismatches between the supply and demand of the residential communities

The supply-demand matching value of residential communities in the midstream was the smallest, and it decreased with increasing riverfront distance (Fig. 5b); 93.92% of the residential communities were identified as the URRS supply-demand mismatches, among which 62.76% were in short supply (mainly located in the midstream) and 37.24% were oversupplied (Fig. 5e). The average supply-demand matching values of residential communities identified as “in short supply,” “balanced,” and “oversupplied” were 0.16, 0.31, and 0.55 m^2/person, respectively. There was a correlation between the spatial clustering of cold and hot spots and the density of residential communities. The denser the residential communities were, the more obvious the cold spots.

3.2.3. Spatial mismatches between the supply and demand of the service region

The supply-demand matching value of the service region in the midstream was the smallest, and it increased with the increasing distance to the city center (Fig. 5c); 50.29% of the service region was identified as the URRS supply-demand mismatch, among which 59.30% was in short supply and 40.70% was oversupplied (Fig. 5f). The average supply-demand matching values of the service region identified as “in short supply,” “balanced,” and “oversupplied” were 0.15, 0.56, and 1.38 m^2/person, respectively. The spatial clustering of cold spots decreased as the riverfront distance decreased. The spatial clustering of hot spots was obvious, and they were mainly located in suburban areas far from the city center, near riverfront parks.

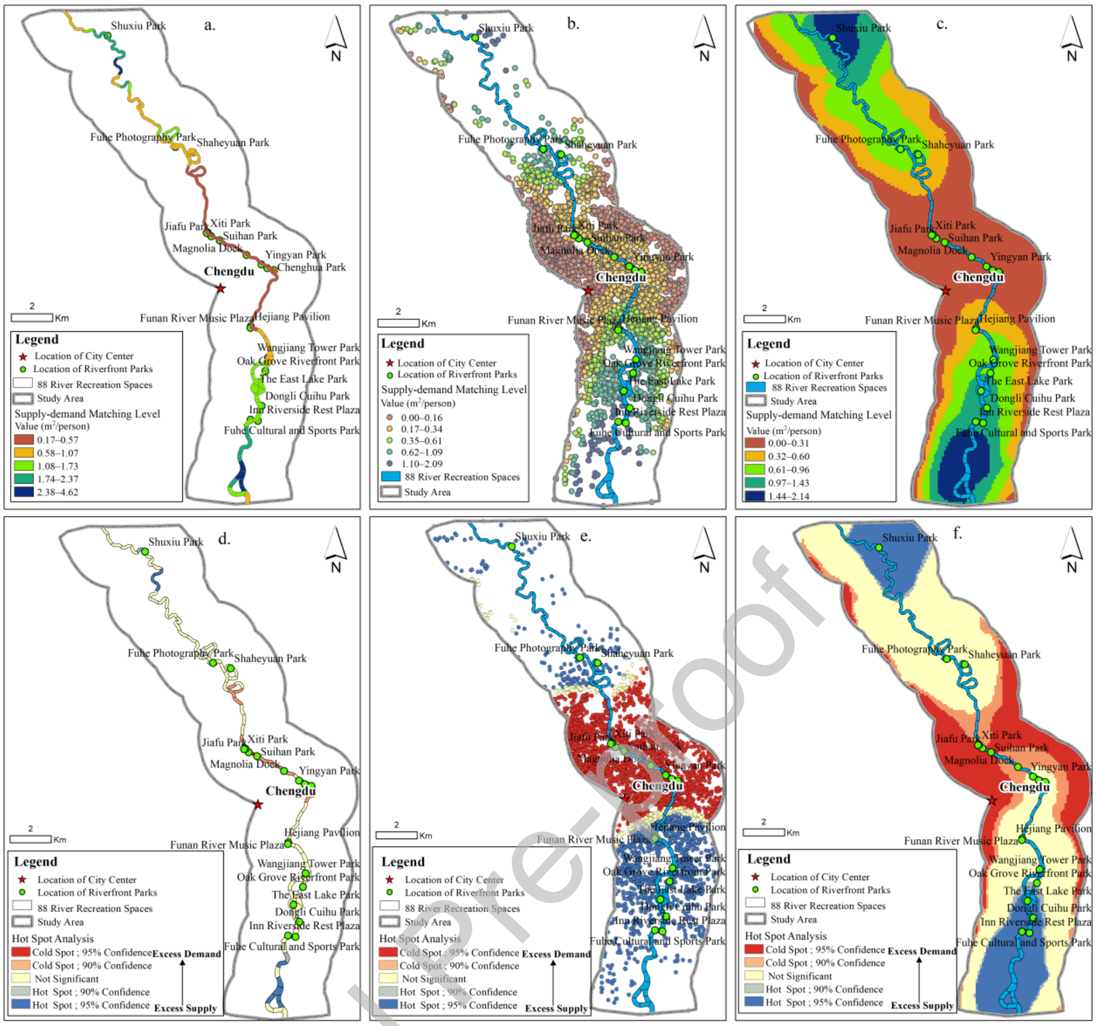

Fig. 5. Spatial mismatches between the supply and demand of urban river recreation services (URRS) (a. Spatial mismatches between the supply and demand of river recreation spaces. b. Spatial mismatches between the supply and demand of residential communities. c. Spatial mismatches between the supply and demand of the service region. d. Spatial distribution of cold and hot spots of river recreation spaces; e. Spatial distribution of cold and hot spots of residential communities. f. Spatial distribution of cold and hot spots of the service region.)

3.3. Influencing factors of spatial mismatches between the URRS supply and demand

3.3.1. Influence intensity

When we combined the classification results of the supply-demand matches of the service region with the influencing factors, we found that the value range of each influencing factor was quite different among the short supply, relatively balanced, and oversupplied regions (Fig. 5). The differences of residential community density and road density in each region were more obvious than those of other influencing factors.

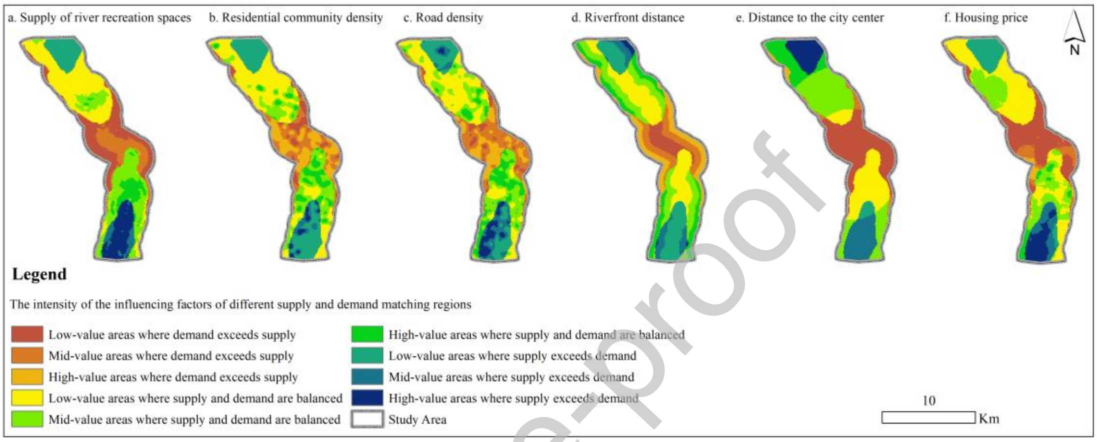

Fig. 5. Differences in influencing factors of different supply and demand matching regions (a. Supply of river recreation spaces; b. Residential community density; c. Road density; d. Riverfront distance; e. Distance to the city center; f. Housing price)

According to the detection results of the factor detector (Tab. 1), the main influencing factors were the “distance to the city center” (0.32), “supply of river recreation spaces” (0.30), “riverfront distance” (0.23), and “residential community density” (0.20). The influence intensity of each factor was different among the short supply, relatively balanced, and oversupplied regions. The difference between “riverfront distance” and “housing price” was quite obvious. The influence intensity of “riverfront distance” was the strongest in the short supply region and the influence intensity of “housing price” was the strongest in the oversupplied region.

Table 1. The influence intensity of each factor in different supply and demand matching regions

Regions Influencing factors	All	Short supply region	Oversupplied region	Relatively balanced region
Supply of river recreation spaces (X1)	0.30	0.20	0.08	0.08
Residential community density (X2)	0.20	0.01	0.04	0.06
Road density (X3)	0.06	0.03	0.01	0.04
Riverfront distance (X4)	0.23	0.33	0.06	0.14
Distance to the city center (X5)	0.32	0.03	0.14	0.13
Housing price (X6)	0.13	0.03	0.22	0.02

3.3.2. Interaction of influencing factors

We used the interactive detector to analyze whether the selected influencing factors had an enhancing or weakening effect on each other. The results showed that the influencing interactions of each factor were all enhanced (Tab. 2). The "distance to the city center" had the strongest interaction with the "supply of river recreation spaces," "riverfront distance," and "housing price." The interaction of "residential community density," "road density," and "distance to the city center" with "supply of river recreation spaces," "riverfront distance," and "housing price" showed nonlinear synergy respectively. That is to say, "residential community density," "road density," and "distance to the city center" enhanced the influence intensity of other factors. These three factors could be used as auxiliary factors to evaluate the spatial differences of the URRS supply-demand matches.

Table 2. The interaction of influencing factors

Influence factors	Influence intensity	Interaction	Influence factors	Influence intensity	Interaction
X1∩X2	0.51	Enhance, nonlinear synergy	X2∩X6	0.37	Enhance, nonlinear synergy
X1∩X3	0.39	Enhance, nonlinear synergy	X3∩X4	0.30	Enhance, nonlinear synergy
X1∩X4	0.49	Enhance, bi-synergy	X3∩X5	0.35	Enhance, bi-synergy
X1∩X5	0.68	Enhance, nonlinear synergy	X3∩X6	0.26	Enhance, nonlinear synergy
X1∩X6	0.42	Enhance, bi-synergy	X4∩X5	0.59	Enhance, nonlinear synergy
X2∩X3	0.21	Enhance, bi-synergy	X4∩X6	0.42	Enhance, nonlinear synergy
X2∩X4	0.44	Enhance, nonlinear synergy	X5∩X6	0.55	Enhance, nonlinear synergy
X2∩X5	0.35	Enhance,			

		bi-synergy			

4. Discussion

4.1. Main contributions and rationality of our comprehensive analysis framework

There are three main contributions of our framework in identifying the URRS supply and demand mismatches. First, our method clearly delineated the boundary of the URRS supply and demand. Due to different research purposes, the delineation of river boundaries is not uniform (Kinley et al., 1997; Dosskey et al., 2002; Bachiller et al., 2019), and there is lack of urban river boundary delineation from the perspective of river recreation. Second, our multi-dimensional evaluation method improved the analysis accuracy of the URRS matching relationships. Rather than only focus on a regional perspective (administrative district or watershed scale) (Larondelle and Lauf, 2016; Meng et al., 2020), our study focuses on three different dimensions of the URRS supply and demand. The differences in the evaluation of these three dimensions further indicate that the density of demanders and their riverfront distance will affect the URRS they capture. Third, we further explored the underlying causes of the URRS supply-demand mismatches by analyzing the interaction between influencing factors. Most researchers have only discussed the independent influence of each factor (Wang et al., 2020; González et al., 2020), but we further quantify the enhancing or weakening effects of different factors.

Our analysis framework is reasonable. In our research, the URRS supply-demand matching value gradually decreased from the urban fringe areas to the central urban areas. This is consistent with most researches on the spatial distribution of cultural ecosystem services supply and demand, such as the supply-demand spatial patterns of urban green spaces (Dai, 2011; Liu et al., 2020; Bing et al., 2021) and ecological space recreation services (Wang et al., 2020).

4.2. Implications for urban river management

The supply-demand matching focus on each dimension is different, and each result can be used to propose targeted urban river management recommendations. The supply-demand matching results of the service supplier and demander dimensions can be used to guide the optimization of the URRS supply and the riverfront residential layout. For example, the Water Ecosystem Plan of Chengdu in 2025 (2015) only proposes the construction of different riverfront landscape nodes according to the regional ecological environment, economy, and water ecosystem characteristics. Our research results further indicate that the riverfront residential community density must also be considered. For high-density areas in short supply, it is necessary to balance the supply of adjacent riverfront recreation space to avoid excessive concentration of recreation crowds. It is also feasible to guide the riverfront residents to relocate to the oversupplied regions, and increase the recreational opportunities for residents.

The analysis result of the service region can be used to guide the optimization of riverfront walking paths and improve the equity of the URRS utilization. For example, the Technical Guidance for the Construction of the "Livable Riverfront" Project in Chengdu (2017) mainly focuses on the planning and construction of road width and materials, without considering the riverfront distance of the residential communities. We recommend maintaining the openness and connectivity of the riverfront walking paths between the upstream and downstream, and constructing multiple entrances and exits to improve the accessibility of river recreation spaces.

4.3. Limitations and prospects for future research

Our analysis framework is applicable to identifying the URRS supply-demand mismatches in these urban rivers, where the demanders are mainly local riverfront residents. Usually, for urban rivers with relatively narrow recreation spaces, the demanders are mainly local riverfront residents. The same situation is found in Logroños riverfront (Spain) (Durán et al., 2021) and Old Nakano river (Japan) (Asakawa et al., 2004). If the urban river is too wide, it will attract more people to enjoy the URRS from farther distance. Therefore, our analysis framework is insufficient in the study of broader urban rivers.

When evaluating the quality of a river recreation space, only the acreage of the river, riverfront green spaces, and riverfront walking paths were considered. Although these three aspects are the basis of the river recreation space, in order to more accurately evaluate the quality of its supply, the configuration of public service facilities (Liu et al., 2021), riverfront landscape vegetation, riverfront environment, and seasonal differences can also be considered. A large number of field investigations are needed in the future, and a comprehensive scoring system should be used to evaluate the quality of the URRS supply. When we assessed the URRS demand, we only considered the total population of the residential communities and did not consider the differences in demand among different groups (Zhang et al., 2020). The gender, age, education, and demand preferences of residents in the community will all affect their URRS demands. In the future, a probability model can be established based on questionnaires to evaluate the URRS supply-demand differences among different groups.

5. Conclusions

Our research proposed a comprehensive analysis framework to identify the spatial mismatches between the URRS supply and demand. This framework could be generally applied to quantify the supply-demand mismatches from multiple dimensions and the interaction between influencing factors. Compared with the existing supply-demand matching researches and the actual situation of the Jinjiang River, our research results were reliable. According to our research results, there were obvious differences among the supply-demand mismatches of the service supplier, the service demander, and the service region. These differences indicated that the competitive relationship among demanders, and the spatial distance between demanders and suppliers should be considered when identifying the URRS supply-demand mismatches. The URRS supply of the Jinjiang River was still insufficient, especially in the midstream near the city center. From the interaction between the influencing factors of the URRS supply-demand matches, we should improve the URRS supply based on the demand, population, and distribution of riverfront residents. For regions with excessive demand, on the one hand, we can guide them to transfer to regions with sufficient supply; on the other hand, we can balance the URRS supply based on the characteristics of each riverfront recreation space, and avoid excessive concentration of recreation crowds.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Asakawa, S., Yoshida, K., & Yabe, K. (2004). Perceptions of urban stream corridors within the greenway system of Sapporo, Japan. *Landscape and Urban Planning*, *68*(2), 167–182. https://doi.org/10.1016/S0169-2046(03)00158-0.

Bachiller-Jareno, N., Hutchins, M. G., Bowes, M. J., Charlton, M. B., & Orr, H. G. (2019). A novel application of remote sensing for modelling impacts of tree shading on water quality. *Journal of Environmental Management*, *230*, 33–42. http://doi.org/10.1016/j.jenvman.2018.09.037.

Beauchamp, M., Malherbe, L., de Fouquet, C., Létinois, L., & Tognet, F. (2018). A polynomial approximation of the traffic contributions for kriging-based interpolation of urban air quality model. *Environmental Modelling & Software*, *105*, 132–152. https://doi.org/10.1016/j.envsoft.2018.03.033.

Belkhiri, L., Tiri, A., & Mouni, L. (2020). Spatial distribution of the groundwater quality using kriging and Co-kriging interpolations. *Groundwater for Sustainable Development*, *11*,100473. https://doi.org/10.1016/j.gsd.2020.100473.

Bing, Z., Qiu, Y., Huang, H., Chen, T., Zhong, W., & Jiang, H. (2021). Spatial distribution of cultural ecosystem services demand and supply in urban and suburban areas: A case study from Shanghai, China. *Ecological Indicators*, *127*, 107720. https://doi.org/10.1016/j.ecolind.2021.107720.

Chen, J., Jiang, B., Bai, Y., Xu, X., & Alatalo, J. M. (2019). Quantifying ecosystem services supply and demand shortfalls and mismatches for management optimisation. *Science of The Total Environment*, *650*, 1426–1439. https://doi.org/10.1016/j.scitotenv.2018.09.126.

Chen, Y., Yue, W., & La Rosa, D. (2020). Which communities have better accessibility to green space? An investigation into environmental inequality using big data. *Landscape and Urban Planning*, *204*, 103919. https://doi.org/10.1016/j.landurbplan.2020.103919.

Dai, D. (2011). Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landscape and Urban Planning*, *102*(4), 234–244. https://doi.org/10.1016/j.landurbplan.2011.05.002.

Dosskey, M., G., Helmers, M., J., Eisenhauer, D., E., Franti, T., G., Hoagland, & K., D. (2002). Assessment of concentrated flow through riparian buffers. *Journal of Soil & Water Conservation*,*57*(6),336-343. https://doi.org/10.1061/(ASCE)0733-9437(2002)128:6(404).

Durán Vian, F., Pons Izquierdo, J. J., & Serrano Martínez, M. (2021). River-city recreational interaction: A classification of urban riverfront parks and walks. *Urban Forestry & Urban Greening*, *59*, 127042. https://doi.org/10.1016/j.ufug.2021.127042.

González-García, A., Palomo, I., González, J. A., López, C. A., & Montes, C. (2020). Quantifying spatial supply-demand mismatches in ecosystem services provides insights for land-use planning. *Land Use Policy*, *94*, 104493. https://doi.org/10.1016/j.landusepol.2020.104493.

Guimarães, L. F., Teixeira, F. C., Pereira, J. N., Becker, B. R., Oliveira, A. K. B., Lima, A. F., Veról, A. P., & Miguez, M. G. (2021). The challenges of urban river restoration and the proposition of a framework towards river restoration goals. *Journal of Cleaner Production*, *316*, 128330. https://doi.org/10.1016/j.jclepro.2021.128330.

Hu, S., Song, W., Li, C., & Lu, J. (2020). A multi-mode Gaussian-based two-step floating catchment area method for measuring accessibility of urban parks. *Cities*, *105*, 102815. https://doi.org/10.1016/j.cities.2020.102815.

Hua, J., & Chen, W. Y. (2019). Prioritizing urban rivers' ecosystem services: An importance-performance analysis. *Cities*, *94*, 11–23. https://doi.org/10.1016/j.cities.2019.05.014.

Ju, H. R., Zhang, Z. X., Zuo, L. J., Wang, J. F., Zhang, S. R., Wang, X., & Zhao, X. L. (2016). Driving forces and their interactions of built-up land expansion based on the geographical detector - a case study of Beijing, China. *International Journal of Geographical Information Science*, *30*(11), 2188–2207. https://doi.org/10.1080/13658816.2016.1165228.

Kinley, TA, Newhouse, & NJ. (1997). Relationship of riparian reserve zone width to bird density and diversity in southeastern British Columbia. *Northwest Sci*, *1997*, *71*(2), 75–86. https://doi.org/10.1046/j.1365-294X.1997.00215.x.

Komossa, F., Wartmann, F. M., Kienast, F., & Verburg, P. H. (2020). Comparing outdoor recreation preferences in peri-urban landscapes using different data gathering methods. *Landscape and Urban Planning*, *199*, 103796. https://doi.org/10.1016/j.landurbplan.2020.103796.

Larondelle, N., & Lauf, S. (2016). Balancing demand and supply of multiple urban ecosystem services on different spatial scales. *Ecosystem Services*, *22*, 18–31. https://doi.org/10.1016/j.ecoser.2016.09.008.

Little, C. E. (1990). Greenways for America. *Johns Hopkins University Press, Baltimore*.

Liu, H., Remme, R. P., Hamel, P., Nong, H., & Ren, H. (2020). Supply and demand assessment of urban recreation service and its implication for greenspace planning-A case study on Guangzhou. *Landscape and Urban Planning*, *203*, 103898. https://doi.org/10.1016/j.landurbplan.2020.103898.

Liu, Z., Huang, Q., & Yang, H. (2021). Supply-demand spatial patterns of park cultural services in megalopolis area of Shenzhen, China. *Ecological Indicators*, *121*, 107066. https://doi.org/10.1016/j.ecolind.2020.107066.

Lorilla, R. S., Kalogirou, S., Poirazidis, K., & Kefalas, G. (2019). Identifying spatial mismatches between the supply and demand of ecosystem services to achieve a sustainable management regime in the Ionian Islands (Western Greece). *Land Use Policy*, *88*, 104171. https://doi.org/10.1016/j.landusepol.2019.104171.

Ma, F. (2020). Spatial equity analysis of urban green space based on spatial design network analysis (sDNA): A case study of central Jinan, China. *Sustainable Cities and Society*, *60*, 102256. https://doi.org/10.1016/j.scs.2020.102256.

Meleason, M. A., & Quinn, J. M. (2004). Influence of riparian buffer width on air temperature at Whangapoua Forest, Coromandel Peninsula, New Zealand. *Forest Ecology & Management*, *191*(1–3), 365–371. https://doi.org/10.1016/j.foreco.2004.01.016.

Meng, S., Huang, Q., Zhang, L., He, C., Inostroza, L., Bai, Y., & Yin, D. (2020). Matches and mismatches between the supply of and demand for cultural ecosystem services in rapidly urbanizing watersheds: A case study in the Guanting Reservoir basin, China. *Ecosystem Services*, *45*, 101156. https://doi.org/10.1016/j.ecoser.2020.101156.

Mo, W., Wang, Y., Zhang, Y., & Zhuang, D. (2017). Impacts of road network expansion on landscape ecological risk in a megacity, China: A case study of Beijing. *Science of The Total Environment*, *574*, 1000–1011. https://doi.org/10.1016/j.scitotenv.2016.09.048.

Othman, A., Al-Hagla, K., & Hasan, A. E. (2021). The impact of attributes of waterfront accessibility on human well-being: Alexandria Governorate as a case study. *Ain Shams Engineering Journal*, *12*(1), 1033–1047. https://doi.org/10.1016/j.asej.2020.08.018.

Peng, J., Yang, Y., Xie, P., & Liu, Y. (2017). Zoning for the construction of green space ecological networks in Guangdong Province based on the supply and demand of ecosystem services. *Acta Ecologica Sinica*, *37*(13), 4562–4572. http://doi.org/10.5846/stxb201601020007.

Peng, J., Zhao, H., & Liu, Y. (2017). Urban ecological corridors construction: A review. *Shengtai Xuebao/ Acta Ecologica Sinica*, *37*(1), 23–30. https://doi.org/10.1016/j.chnaes.2016.12.002.

Potestio, M. L., Patel, A. B., Powell, C. D., Mcneil, D. A., Jacobson, R. D., & Mclaren, L. (2009). Is there an association between spatial access to parks/green space and childhood overweight/obesity in Calgary, Canada? *International Journal of Behavioral Nutrition & Physical Activity*, *6*(1), 77. https://doi.org/10.1186/1479-5868-6-77.

Tao, Z., Zhou, J., Lin, X., Chao, H., & Li, G. (2020). Investigating the impacts of public transport on job accessibility in Shenzhen, China: a multi-modal approach. *Land Use Policy*, *99*, 105025. https://doi.org/10.1016/j.landusepol.2020.105025.

Technical guidelines for the construction of "livable riverfront" project in Chengdu. (2017). Bureau, Chengdu Municipal Housing And. https://wenku.baidu.com/view/cde4038e854769eae009581b6bd97f192279bfeb.html

The Water Ecosystem Planning Plan of Chengdu in 2025. (2015). Authority, Chengdu Water. http://cdwater.chengdu.gov.cn/cdsswj/c109465/2015-07/08/content_d24b7ab3c62b4bc284fc4e13b62781b3.shtml

Wang, F., Wang, K., & Liu, H. (2020). Evaluation and influence fators of spatial accessibility of ecological space recreation service in the Pearl River Delta Urban Agglomeration: a modified Two-step Floating Catchment Area method. *Acta Ecologica Sinica*, *11*, 1–13. http://doi.org/10.5846/stxb201901060046.

Wang, H., Wu, Q., Hu, W., Huang, B., Dong, L., & Liu, G. (2018). Using multi-medium factors analysis to assess heavy metal health risks along the Yangtze River in Nanjing, Southeast China. *Environmental Pollution*, *243*, 1047–1056. https://doi.org/10.1016/j.envpol.2018.09.036.

Wang, J. F., Li, X. H., Christakos, G., Liao, Y. L., Zhang, T., Gu, X., & Zheng, X. Y. (2010). Geographical Detectors-Based Health Risk Assessment and its Application in the Neural Tube Defects Study of the Heshun Region, China. *International Journal of Geographical Information Science*, *24*(1), 107–127. https://doi.org/10.1080/13658810802443457.

Wang, J., & Xu, C. (2017). Geodetector:Principle and prospective. *Acta Geographica Sinica*, *72*(01), 116–134. https://doi.org/10.11821/dlxb201701010.

Washbourne, C.-L., Goddard, M. A., Le Provost, G., Manning, D. A. C., & Manning, P. (2020). Trade-offs and synergies in the ecosystem service demand of urban brownfield stakeholders. *Ecosystem Services*, *42*, 101074. https://doi.org/10.1016/j.ecoser.2020.101074.

Wei, F. (2017). Greener urbanization? Changing accessibility to parks in China. *Landscape and Urban Planning*, *157*, 542–552. https://doi.org/10.1016/j.landurbplan.2016.09.004.

Wei, Y., Xiu, C., Gao, R., & Wang, Q. (2014). Evaluation of green space accessibility of Shenyang using Gaussian based 2-step floating catchment area method. *Progress in Geography*, *33*(04), 479–487. https://doi.org/10.11820/dlkxjz.2014.04.005.

Wilkerson, M. L., Mitchell, M. G. E., Shanahan, D., Wilson, K. A., Ives, C. D., Lovelock, C. E., & Rhodes, J. R. (2018). The role of socio-economic factors in planning and managing urban ecosystem services. *Ecosystem Services*, *31*, 102–110. https://doi.org/10.1016/j.ecoser.2018.02.017.

Xie, W., Huang, Q., He, C., & Zhao, X. (2018). Projecting the impacts of urban expansion on simultaneous losses of ecosystem services: A case study in Beijing, China. *Ecological Indicators*, *84*, 183–193. https://doi.org/10.1016/j.ecolind.2017.08.055.

Xing, L., Liu, Y., Liu, X., Wei, X., & Mao, Y. (2018). Spatio-temporal disparity between demand and supply of park green space service in urban area of Wuhan from 2000 to 2014. *Habitat International*, *71*, 49–59. https://doi.org/10.1016/j.habitatint.2017.11.002.

Xing, L., Liu, Y., Wang, B., Wang, Y., & Liu, H. (2020). An environmental justice study on spatial access to parks for youth by using an improved 2SFCA method in Wuhan, China. *Cities*, *96*, 102405. https://doi.org/10.1016/j.cities.2019.102405.

Yue, J., Wang, Y., & Peng, J. (2005). A conceptual framework for the study of urban river based on landscape ecology. *Acta Ecologica Sinica*, *25*(06), 1422–1429. https://doi.org/10.3321/j.issn:1000-0933.2005.06.029.

Zhang, J., Cheng, Y., & Zhao, B. (2021). How to accurately identify the underserved areas of peri-urban parks? An integrated accessibility indicator. *Ecological Indicators*, *122*, 107263. https://doi.org/10.1016/j.ecolind.2020.107263.

Zhang, T., Xu, X., & Xu, S. (2015). Method of establishing an underwater digital elevation terrain based on kriging interpolation. *Measurement*, *63*, 287–298. https://doi.org/10.1016/j.measurement.2014.12.025.

Zhang, T. N., Song, H., Zhou, B., Wang, L., Yang, A., Wang, T., Kong, H., Chen, Y., Zhou, S., & Fu, S. (2021). Effects of air pollutants and their interactive environmental factors on winter wheat yield. *Journal of Cleaner Production*, *305*, 127230. https://doi.org/10.1016/j.jclepro.2021.127230.

Zhang, X., Ni, Z., Wang, Y., Chen, S., & Xia, B. (2020). Public perception and preferences of small urban green infrastructures: A case study in Guangzhou, China. *Urban Forestry & Urban Greening*, *53*, 126700. https://doi.org/10.1016/j.ufug.2020.126700.

Zhou, X., & Wang, Y.-C. (2011). Spatial-temporal dynamics of urban green space in response to rapid urbanization and greening policies. *Landscape and Urban Planning*, *100*(3), 268–277. https://doi.org/10.1016/j.landurbplan.2010.12.013.