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Spatial Distribution Changes in Nature-Based Recreation Service Supply from 2008 to 2018 in Shanghai, China

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Abstract: Nature-based recreation has become an important activity in contemporary society and a key component of cultural ecosystem services. Although the methods of mapping the outdoor recreation supply have been gradually improved, few studies have carried out multi-temporal evaluations. Based on land use/land cover (LULC), POI, and other web-open data, we mapped the recreational service supply in Shanghai in 2008 and 2018, combining recreation potential and recreation opportunities. We first selected the evaluation indicators, using LULC to measure recreational potential, and POI density and accessibility to measure recreational opportunities. Then, we used principal component analysis (PCA) to determine the weights of the 12 factors that measure recreational opportunities, and made RO and RP maps, respectively. Finally, we overlaid RO and RP maps to obtain the spatial distribution map of recreation service supply. Our results showed that the supply of recreation services in 2008 and 2018 presented a "V-shaped" gradient along the city center areas—the peri-urban areas—the rural areas. Compared with the year 2008, the average recreation value decreased in nine regions, but increased in Chongming District in 2018. The assessment and mapping of recreation service supply value provide a basis for the development of local recreational resources, land use decisions, and the management of recreational cultural ecosystem services.

Keywords: nature-based recreation; cultural ecosystem service; mapping; recreation opportunity and potential; multi-source data

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Citation: Liu, S.; Shen, P.; Huang, Y.; Jiang, L.; Feng, Y. Spatial Distribution Changes in Nature-Based Recreation Service Supply from 2008 to 2018 in Shanghai, China. *Land* **2022**, *11*, 1862. https://doi.org/10.3390/land11101862

Academic Editors: Maurizio Pollino, Sergio Cappucci, Andrea Taramelli and Shaojian Wang

Received: 7 September 2022
Accepted: 19 October 2022
Published: 20 October 2022

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1. Introduction

Ecosystem services (ES) are commonly defined as the "benefits that people obtain from ecosystems" and are generally classified into provisioning services, regulating services, supporting services and cultural services. Cultural ecosystem services (CES) are the "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences". This concept was further expanded to include: recreation, aesthetic, spiritual and religious, inspirational, local feeling, sense of place, cultural heritage, educational, and so on [1]. Among them, recreation services refers to the entertainment and leisure cultural services provided by the ecosystem based on the natural or semi-natural landscape [2]. Recreation services have a positive impact on the public's physical and mental health and contribute to human well-being [3–6].

In recent years, quantitative evaluation of recreation services has attracted extensive attention from researchers, which can provide theoretical support for the optimization of urban land use pattern, rational development of recreation resources, and the optimal regulation of cultural ecosystem services [7,8]. "Evaluation" means the process of assessing the value of something. The scientific literature has proposed a series of terms to distinguish specific methodological approaches, often used synonymously, including valuation, assessment, mapping, quantifying, accounting, and so on [9]. The evaluation of CES is relatively poorly mapped and understood as CES are "nonmaterial", "intangible" and "invisible" compared with other material services [1,10,11]. Nonetheless, researchers have been studying CES and their evaluation methods for decades [12–14]. The application of geographic information systems (GIS) to simulate the geographical distribution of service volume has become an important method to evaluate the recreation service [15]. At the same time, more and more studies use the framework of recreation potential and recreation opportunities to assess and map the recreation supply [14,16–18]. The final assessment results can play an important role in guiding land management [19].

Researchers established a framework for evaluating the supply potential of different landscape types that provide ecosystem services based on land use data, combined with social and economic data [20]. The supply opportunity of recreation ecosystem service was characterized by traffic, facility accessibility, and population density [21]. As basic information service for the public, open data on the network platform helps researchers realize remote surveys and provides them with diverse data. In recent years, city points of interest (POI) and other web-open data have been widely used in urban research. It has been proved that good service infrastructure networks, such as restaurants, entertainment facilities can better meet the preferences of the crowd and help to facilitate more recreational activities [11,22,23]. The distribution of POI reflects the degree of infrastructure perfection and, like accessibility, represents spatial recreation opportunity (RO), which can be used to evaluate recreation.

With the rapid urbanization, there are more and more studies on the assessment of urban recreational ecosystem services. Some studies have evaluated the provision of recreational services in a certain area of the city, such as the city center, the peri-urban and the rural areas [24,25]. Other studies have measured the recreation service supply of different types of land, such as forests, urban parks, urban remnant mountain wilderness, urban river, oceans, farmlands, and so on [26–32]. Recreation services are closely related to the health and well-being of every urban resident. Mapping urban recreation services is an important basis for studying the spatial heterogeneity and equity of recreation services. However, few studies have been conducted to measure the supply of recreational ecosystem services in the whole city.

In addition, rapid urbanization makes ecosystems subject to strong interferences of different kinds of human activities, and leads to the decline of many ecosystem services. Urbanization significantly affects all ecosystem services, and changes in ecosystem services, including recreation services, are spatially heterogeneous due to urban expansion and population movement [33–35]. Although the methods of mapping the outdoor recreation supply have been gradually improved, previous studies mainly focused on one time section, and few studies carried out multi-temporal evaluations [36]. By mapping the spatial distribution of outdoor recreation service supply of different periods and comparing the results, the spatio-temporal changes and driving forces can be found comprehensively, which benefit the planning and decision-making of recreational facilities in the future. Therefore, the following questions are raised:

(1) Are there differences in the provision of recreational ecosystem services between urban centers, peri-urban areas, and rural areas in rapidly urbanizing cities?
(2) What are the spatio-temporal changes in the supply of urban recreation services during the rapid urbanization process?
(3) What factors cause the spatio-temporal changes of recreation service supply?

The purposes of this study is to map the supply of outdoor recreation service considering recreation potential (RP) and recreation opportunity (RO) with multi-source data. We take Shanghai as an example for research, and analyze the spatial distribution changes of recreation service supply from 2008 to 2018. It is hoped that this study can provide reference for other rapidly urbanizing cities, and also provide suggestions for land use planning and recreation resource allocation.

2. Materials and Methods

2.1. Study Area

Shanghai, as the leading city of the Yangtze River Delta (120°52′–122°12′ E, 30°40′–31°53′ N) and the economic and financial center of China, is located in the China's eastern coast, covering an area of about 6340 km^2 (Figure 1). The city has a population of 24 million in 2018, and is one of the most densely populated cities in the world.

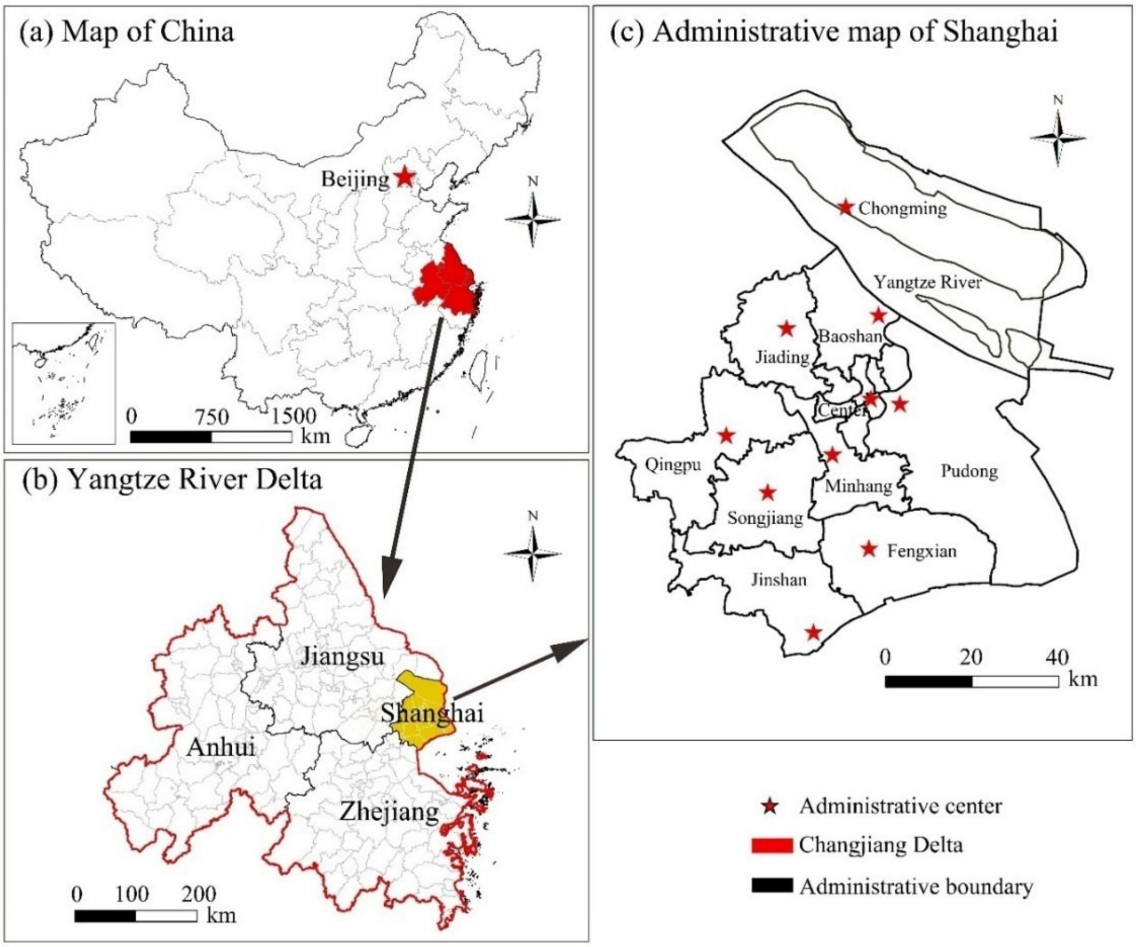

Figure 1. The geographic location of Shanghai. (**a**) location of Shanghai in China; (**b**) location of Shanghai in Yangtze River Delta; (**c**) administrative map of Shanghai.

Over the past two decades, Shanghai has witnessed an economic prosperity, population explosion, and rapid urbanization [37]. This has not only brought a series of ecological risks such as the loss of agricultural and natural land, but also increased demands from residents for improving the living environment and for better natural recreation places [38]. To meet this rapidly rising demand, some measures have been taken by the government. For example, 45 km of public space along the Huangpu River opened up in 2017 and more than 30 country parks are planned to be built according to the Shanghai Master Plan (2017–2035).

2.2. Theoretical Basis

The type of recreation that we approached in this study is the so-called nature-based recreation, outdoor recreation or soft ecotourism [39]. To map outdoor recreation as an ecosystem service, it is necessary to know the main factors that influence the behavior of people when they recreate. The previous literature on outdoor recreation spatial mapping generally considered recreationists as a single user group, and a few studies also took the personal characteristics of users, such as socioeconomic, social status, environmental attitudes, living locations, and familiarity into consideration [40,41]. In fact, recreation maps of different user groups show obvious spatial similarities, especially in the high-value areas of coastal and mountain areas such as lakes, oceans, and rivers, and the following rules can be found: (1) urbanizations have a negative impact on recreation potential; (2) forests and water exert a specific attraction; (3) different from grassland, arable land is not recorded as being particularly attractive for recreation in nature; (4) more natural sites seem more attractive than areas of higher anthropic influence; (5) travel distances are relatively short: intimate visits take place in about 10 min;

The study is on the basis of the assumption that within outdoor recreation, recreationists' preferences are based on an array of elements including landscape attributes, accessibility, and specific facilities [14].

2.3. Data Collection

The type of recreation that we approached in this study is the outdoor recreation [39]. Two components were considered for mapping the recreation service: the recreation potential (RP) and the recreation opportunity (RO). In order to map the recreation ecosystem service, a multi-source database composed of different geospatial data was required (Table 1). All information was then projected onto the same coordinate system (WGS_1984_UTM_ZONE_51N) to facilitate spatial analysis.

Table 1. Multi-source geospatial database developed for the case study.

Data	Data Type	Data Source	Description
Land use/cover map	Raster data	Resource and Environment Data Cloud Platform (2008, 2018) (http://www.resdc.cn/ (accessed on 20 November 2019))	Different types of land use including cultivated land, forest land, grassland, waters, residential land and unused land in Shanghai (30 m).
Population density	Raster data	World Pop (2008, 2018) (https://www.worldpop.org/ (accessed on 25 November 2019))	Population density of Shanghai (100 m).
City center	Vector data	Administrative map	City center of Shanghai.
Administrative center	Vector data	Administrative map	Administrative center of Shanghai.
Road network	Vector data	NavInfo Co, Ltd. (2010, 2018) (https://www.navinfo.com/ (accessed on 25 November 2019))	Different types of roads including national roads, provincial roads, motorways, urban expressways in Shanghai
City POI	Vector data	Gaode map (2018) (https://www.amap.com/ (accessed on 28 November 2019)) and Baidu map (2010) (https://www.baidu.com/ (accessed on 28 November 2019))	Different types of city POI including living point, shopping point, catering point, service point, tourist spot, entertainment facilities.
Bus stations	Vector data	Gaode map (2018) (https://www.amap.com/ (accessed on 21 November 2019)) and Baidu map (2010) (https://www.baidu.com/ (accessed on 21 November 2019))	Bus stations in Shanghai.
Subway stations	Vector data	Gaode map (2018) (https://www.amap.com/ (accessed on 22 November 2019)) and Baidu map (2010) (https://www.baidu.com/ (accessed on 22 November 2019))	Subway stations in Shanghai.

2.3.1. Recreation Potential

Land use explains a considerable part of the variation in the spatial supply of ES [20,42]. Based on the land use and land cover types, this paper calculated the recreation potential of different ecosystems. In this study all ecosystems were included in the analysis including cultivated land, forest land, grassland, waters, residential land, unused land, and urban green space, regardless of the intensity of human use and change. Although their scopes of supply varied according to the characteristics, all ecosystems were considered as potential providers of recreation service [14,43].

Land use data of 2008 and 2018 were sourced from Resource and Environment Data Cloud Platform (http://www.resdc.cn/ (accessed on 20 November 2019)), produced by Institute of Geographic Sciences and Natural Resources Research, CAS (Figure 2). It is generated by manual visual interpretation of Landsat 8 remote sensing image on the basis of the previous land use remote sensing monitoring data. It includes 6 primary types, which are cultivated land, forest land, grassland, waters, residential land, and unused land, and 25 secondary types. Since urban green plays an important role in the perceived attractiveness, even at a national scale, so it may lead to a serious bias in ES maps if we ignore the potential positive effect of urban green on the supply of recreational opportunities [21]. Based on this, we combined the corresponding urban green space and obtained a land use map that met the requirements of this study.

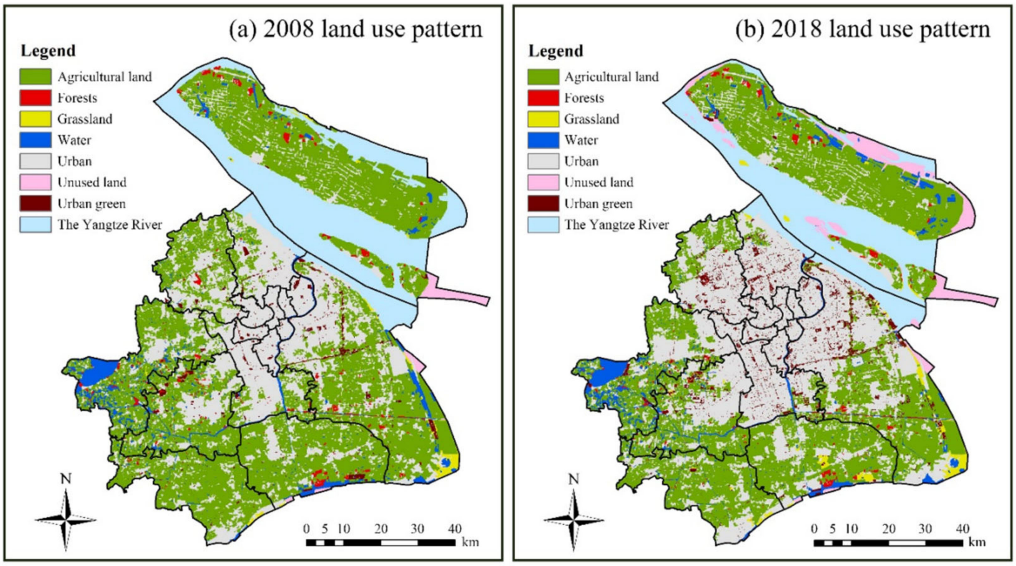

Figure 2. Land use patterns of Shanghai in 2008 and 2018. (**a**) Land use patterns of Shanghai in 2008; (**b**) Land use patterns of Shanghai in 2018.

To estimate the recreation supply of the different land uses/covers, we used the assessment strategy proposed by Burkhard et al. [20]. The basic idea of the assessment strategy is to analyze existing landscape data to assess the ability of different land use/cover to provide ecosystem services spatially. Each land cover type is linked with a score representing the capacity to provide various ecosystem services which are graded by experts and the judgments can be modified according to different measurements, modeling or other expert assessments [44]. Therefore, the assignments in Table 2 were set up based on the experts' judgment for of the same land types in previous studies and the actual situation in Shanghai.

Table 2. The evaluation index system composed of recreation potential.

Component	Variable	Description
Recreation potential	Land use/cover	Agricultural land (2) Forests (5) Grassland (3) Urban (1) Water (5) Urban green (3) Unused land (4) The Yangtze River (1)

Number in bracket is the recreation supply score graded by experts based on land use types and the situation of Shanghai.

2.3.2. Recreation Opportunity

Some research has shown that recreation value is also influenced by the accessibility of ecosystems to humans and the proximity to population centers, as well as major roads, because it is necessary that people reach sites in order to benefit from this ES [45–47]. Meanwhile, it has been also proved that good infrastructure networks such as catering facilities and entertainment infrastructures can help to facilitate more recreational activities [11,23]. Further evidence is also present in surveys and the analyzed literature: water exerts a specific attraction to people from all regions at the regional scale [14,21]. Therefore, we took recreation opportunity (RO) into consideration. It was mapped considering 12 different factors other than land use/cover (Table 3) and we valued each factor using different data and indicators.

Table 3. The evaluation index system composed of recreation opportunity.

Component	Variable	Description
Recreation opportunity	Distance from water body x_1	Euclidean distance
	Population density x_2	Euclidean distance
	Distance from the center of Shanghai x_3	Euclidean distance
	Distance from the center of each administrative region x_4	Euclidean distance
	Distance from road x_5	Euclidean distance
	Distance from bus and subway station x_6	Euclidean distance
	Residential land density x_7	Kernel density analysis
	City poi (entertainment facilities) x_8	Kernel density analysis
	City poi (tourist spots) x_9	Kernel density analysis
	City poi (shopping points) x_{10}	Kernel density analysis
	City poi (service points) x_{11}	Kernel density analysis
	City poi (catering points) x_{12}	Kernel density analysis

The maps of Chinese population density at 100 m resolution in 2008 and 2018 collected from World Pop have been used as a source of information on population distribution in Shanghai (https://www.worldpop.org/ (accessed on 25 November 2019)). According to the administrative boundary of Shanghai, we intercepted the population map and obtained the population distribution data used for this study. Of the vector-formatted datasets, the administrative map was used to define the boundary, city center and administrative centers. The road network data are provided by NavInfoCo, Ltd. (https://www.navinfo.com/ (accessed on 25 November 2019)), and contains space location information of all paved roads in Shanghai including national roads, provincial roads, motorways, and urban expressways. The location of bus and subway stations providing easy access between sub-regions of Shanghai was also collected from the Gaode map and Baidu map using a web crawler. In view of the difficulty in obtaining the spatial distribution information of facilities such as living, shopping, catering, entertainment, and tourism, we used POI data to obtain the above-mentioned facility information, including name, address, latitude and longitude, districts, and counties, through the POI interface of the Gaode map (https://www.amap.com/ (accessed on 28 November 2019)) and Baidu map (https://www.baidu.com/ (accessed on 28 November 2019)) through a web crawler. All datasets could be compiled in vector and raster formats. We rasterized the vector file according to its attribute data to facilitate the posterior analysis using GIS software. The final raster datasets used in this study had a consistent spatial resolution of 100 m.

2.4. Data Analysis

PCA is an objective parameterization method which processes the dataset without considering the dependent variables and then estimates a weighting factor for each variable [48]. PCA uses an orthogonal transformation to identify uncorrelated principal components from candidate factors, which captures the internal structural relationships among all factors [49]. In this study, the recreation opportunity (RO) score (the dependent variable) is unknown. So, we take the PCA method to retrieve the weight of each RO factor, avoiding the disadvantages that may be caused by subjective parameterization in methods such as expert evaluation. Each principal component reflects one aspect of the independent variables. These selected principal components should be able to explain more than 75% of the total variance, with no information repeated [48].

To carry out PCA analysis, we first used the fishing net tool of GIS to sample 12 raster layers and got 8056 sampling points. Then we normalized the sampled data according to the following formulas to construct a standard matrix.

$$\begin{cases} X_i = \frac{x_i - x_{imin}}{x_{imax} - x_{imin}} \\ X'_i = \frac{x_{imax} - x_i}{x_{imax} - x_{imin}} \end{cases} \tag{1}$$

where Xi is the value of positive index after normalization, X'_i is the value of negative index after normalization, x_i is the original index value, x_{imin} is the minimum value of the index, and x_{imax} is the maximum value of the index.

SPSS statistics 23.0 software was used to gain the eigenvalue and contribution ratios from principal component analysis to assess relative importance. We also obtained the load matrix and correlation coefficient matrix from principle component analysis. The weight of the principal component and each factor among the twelve can be calculated using the following formulas [50].

$$W_i = \frac{\lambda_i}{\sum_{i=1}^{n} \sqrt{\lambda_i}} \tag{2}$$

where W_i is weight of the ith principal component and λ_i is eigenvalue of the ith principal component.

$$\begin{cases} F_1 = a_1 x_1 + b_1 x_2 + \ldots + l_1 x_{12} \\ F_2 = a_2 x_1 + b_2 x_2 + \ldots + l_2 x_{12} \\ \ldots \\ F_i = a_i x_1 + b_i x_2 + \ldots + l_i x_{12} \end{cases} \tag{3}$$

where F_i is the ith principal component, x_j is one of the recreation opportunity (RO) factor (j = 12), and a_i, b_i, ... l_i are the correlation coefficient matrices for the ith RO factor.

$$F = \sum_{i=1}^{n} W_i F_i \tag{4}$$

$$F = \sum_{i=1}^{n} W_i (a_i x_1 + b_i x_1 + \ldots l_i x_{12}) \tag{5}$$

where F is the grading score for recreation opportunity, W_i is the weight of the ith principal component, F_i is the ith principal component, x_j is one of the recreation opportunity (RO) factor (j = 12), and a_i, b_i, ... l_i are the correlation coefficient matrices for the ith RO factor.

We superimposed the evaluation results of RP and RO to obtain the final recreation supply maps of Shanghai in 2008 and 2018. By comparing with remote sensing satellite images, we analyzed the evaluation results and explain the possible reasons. Meanwhile, the evaluation results at different times also showed the spatial distribution changes of recreation supply. Combined with the relevant construction process and policy changes in Shanghai, the driving factors that affected the distribution changes were explored as well.

3. Results

3.1. Recreation Potential (RP) and Recreation Opportunity (RO) Maps

Figure 3 shows the spatial distribution of recreation potential based on land use and land cover types in Shanghai. It shows that, with the acceleration of urbanization, the low-value area of recreation potential expands from the city center areas to the rural areas from 2008 to 2018.

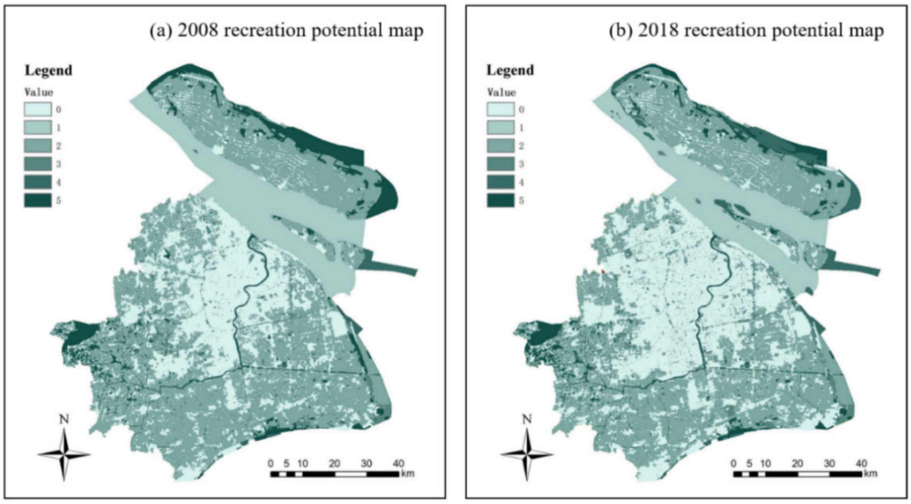

Figure 3. Recreation potential map of Shanghai in 2008 and 2018.

In terms of land use/cover, urban land and agricultural land were the main land use/cover types of Shanghai in 2008 and 2018, accounting for more than 75% of the total area, which brought limited RP supply. The land use/cover has changed dramatically during the past ten years with built-up areas expanding especially in Pudong, Songjiang, Jiading and Qingpu districts. The area around the outer ring was with the most significant urbanization expansion, so the decline in its recreation value was also the most obvious. Agricultural lands were the largest source of newly built-up lands in Shanghai. Among the sharp reduction of 17.8% agricultural land, most of them were converted to urban use and a small proportion was transformed into urban green. This undermines the ability of the land to provide ecosystem services in general and can explain the diminishing value of RP in suburban area. Meanwhile, it can be found that the number of high-value areas with recreational potential in Chongming District increased in 2018 compared with that in 2008, mainly because a large area of unused tidal flat has been formed due to long-term sediment deposition [51], and this type of land use/cover has great potential recreation supply [20]. Furthermore, the "Qingcaosha" reservoir in Chongming District which is an excellent water source and strategic reserve of urban water supply was completed in 2009.

To map the RO, a correlation coefficient matrix was generated by principal component analysis. The first three principal components of selected factors were extracted, producing a total cumulative variance of 77.166% and 78.206% for 2008 and 2018, respectively. Expressions of three principal components in 2008 and 2018 are listed according to formulas.

$$\begin{cases} F_1 = -0.004x_1 + 0.120x_2 + 0.096x_3 + 0.075x_4 + 0.059x_5 + 0.056x_6 + 0.148x_7 \\ \quad +0.153x_8 + 0.125x_9 + 0.149x_{10} + 0.152x_{11} + 0.150\,x_{12} \\ F_2 = 0.224x_1 - 0.011x_2 + 0.151x_3 + 0.266x_4 + 0.386x_5 + 0.391x_6 - 0.064x_7 \\ \quad -0.103x_8 - 0.070x_9 - 0.110x_{10} - 0.108x_{11} - 0.068\,x_{12} \\ F_3 = 0.665x_1 - 0.038x_2 - 0.471x_3 - 0.340x_4 - 0.054x_5 + 0.195x_6 + 0.063x_7 \\ \quad +0.082x_8 + 0.057x_9 + 0.101x_{10} + 0.091x_{11} + 0.082\,x_{12} \end{cases} \tag{6}$$

$$F = 0.656F_1 + 0.219F_2 + 0.125F_3 \tag{7}$$

$$\begin{cases} F_1 = -0.036x_1 + 0.114x_2 + 0.097x_3 + 0.074x_4 + 0.055x_5 + 0.051x_6 + 0.145x_7 \\ \quad +0.151x_8 + 0.123x_9 + 0.141x_{10} + 0.152x_{11} + 0.150\,x_{12} \\ F_2 = 0.070x_1 - 0.016x_2 + 0.171x_3 + 0.286x_4 + 0.452x_5 + 0.434x_6 - 0.083x_7 \\ \quad -0.089x_8 - 0.106x_9 - 0.099x_{10} - 0.090x_{11} - 0.096\,x_{12} \\ F_3 = 0.650x_1 - 0.007x_2 - 0.400x_3 - 0.267x_4 + 0.074x_5 + 0.255x_6 + 0.042x_7 \\ \quad +0.058x_8 + 0.160x_9 + 0.082x_{10} + 0.057x_{11} + 0.064\,x_{12} \end{cases} \tag{8}$$

$$F = 0.672F_1 + 0.189F_2 + 0.139F_3 \tag{9}$$

Among them, the first principal component (F_1) had remarkable higher loads for City POI (entertainment facilities), City POI (service points), and City POI (catering points). Therefore, it can be defined as the characteristics of infrastructure network. The second principal component (F_2) had high loads for Distance from road and Distance from bus and subway station. It can be defined as the accessibility feature. The third principal component (F_3) had high loads for Distance from water body and Distance from the center of Shanghai, followed by Distance from the center of each administrative region, so it can be defined as the location characteristics. The coefficient of each factor can be then defined by the first three principal components and represented as:

$$\begin{cases} F_{2008} = 0.130x_1 + 0.072x_2 + 0.038x_3 + 0.065x_4 + 0.116x_5 + 0.147x_6 + 0.091x_7 \\ \qquad +0.088x_8 + 0.074x_9 + 0.086x_{10} + 0.087x_{11} + 0.094\,x_{12} \\ F_{2018} = 0.081x_1 + 0.073x_2 + 0.042x_3 + 0.067x_4 + 0.133x_5 + 0.152x_6 + 0.088x_7 \\ \qquad +0.093x_8 + 0.085x_9 + 0.087x_{10} + 0.093x_{11} + 0.092\,x_{12} \end{cases} \tag{10}$$

From the results, the coefficient of each factor in 2018 and 2008 shows strong consistency. The coefficients in Equation (10) show that Distance from bus and subway station is the dominant RO factor followed by Distance from road. Compared with 2008, the coefficients of the five infrastructure network elements in 2018 are mostly increased, which shows that the importance of infrastructure construction is gradually strengthening. On the other hand, in 2018, the factor of Distance from the water body has a significant decrease, indicating that it no longer constitutes a major factor affecting RO in 2018.

Figure 4 is based on the principal component analysis of recreation opportunity factors in 2008 and 2018. It can be found that: (1) The highest value of RO in 2008 was 0.949, and the lowest value was 0.12; In 2018, the highest value of RO was 0.959, and the lowest value was 0.081. It can be seen that the RO difference of Shanghai in 2018 is larger than that of 2008, indicating that the polarization trend of Shanghai's overall RO is increasing. (2) In 2008 and 2018, the RO of the city center of Shanghai (including Huangpu District, Xuhui District, Changning District, Jingan District, Putuo District, Hongkou District, and Yangpu District) was high as a whole mainly because of better accessibility and infrastructure networks, while the RO of 9 surrounding administrative districts was low. (3) Compared with 2008, the internal differences of the RO in the nine surrounding administrative regions increased in 2018, and areas with high RO values tended to be centered, which may be due to the higher concentration of various service facilities in the process of gradual completion of small towns in the suburbs. On the other hand, the past decade has also witnessed more obvious residential clustering in Shanghai with rural migrants generally living in the outer suburban areas, whereas urban migrants concentrated in the areas close to the central city area [50], bringing more demand for recreation nearby.

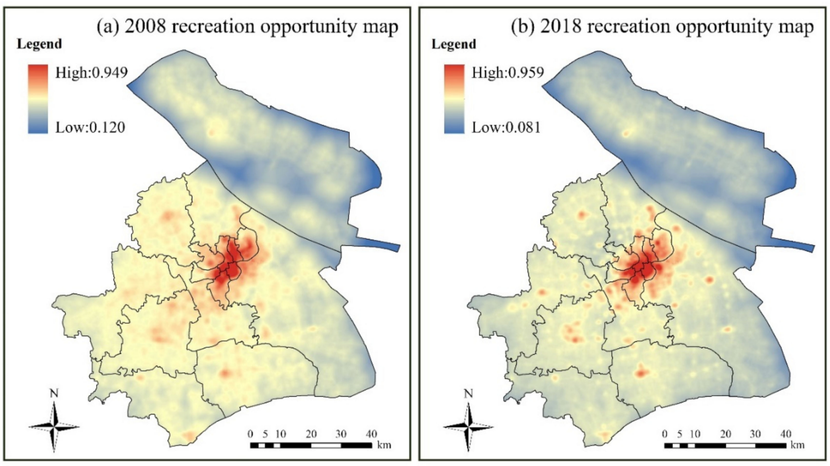

Figure 4. Recreation opportunity map of Shanghai in 2008 and 2018.

3.2. Recreation Service Supply Map

The RP map and the RO maps were subsequently superimposed and normalized to obtain the final map of the recreation service supply capacity value maps (Figure 5). It can be found that:

(1) The supply of recreation services in 2008 and 2018 showed a "V-shaped" gradient along the city center areas—the peri-urban areas—the rural areas.
(2) In 2008 and 2018, the recreation supply capacity of the city center of Shanghai was relatively high, while the RP value was low, and the RO value was high. In general, although the central urban area has little nature-based recreation value from the perspective of land use, it scores high from the perspective of recreation opportunity due to the concentration of population and the complete infrastructure. Places for outdoor activities can form a huge attraction here.
(3) There were "depressions" of recreation supply capacity in the peri-urban areas, including nine districts (including Minhang District, Baoshan District, Jiading District, Pudong District, Jinshan District, Songjiang District, Qinpu District, Fengxian District, and Chongming District), which had low RP and low RO.
(4) In 2008 and 2018, the recreational supply capacity of rural areas in Shanghai's nine districts were relatively high, and the RP and RO value were medium. A large area of farmland is distributed around the urban area. Although the recreation value of farmland itself is limited, combined with the surrounding waters and woodland, it can also form a scenic leisure place. In addition, the accessibility and the construction of service facilities of suburban area is relatively complete so that such places exert great value of ecosystem cultural services, while also having other outstanding ecological benefits.
(5) Several ecological conservation areas (lakes and wetlands in Qingpu District, Pudong District, Fengxian District, and Chongming District) in Shanghai have the highest recreational supply capacity value, and these areas have a high RP and low RO.

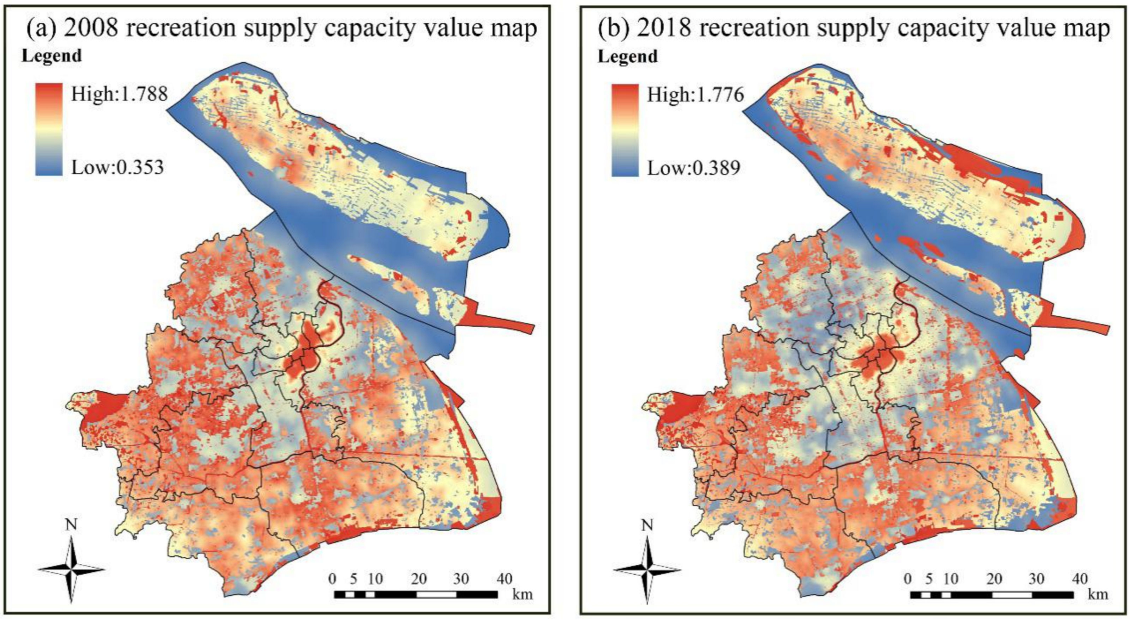

Figure 5. Recreation supply capacity value maps of Shanghai in 2008 and 2018.

3.3. Spatial Distribution Changes of Recreation Supply from 2008 to 2018

Through the comparison of recreation value maps of the two time periods, we found that the average recreation supply capacity value increased in Chongming District, but decreased in other nine regions from 2008 to 2018 (Figure 6). The area statistics showed that compared with 2008, 19.6% of the study area experienced recreation value changed in 2018. The area where the recreation value decreased was 944.81 km^2, accounting for 11.7% of the total area, and the area with an increase in recreation value was 634.50 km^2, accounting for 7.9%, while the rest of the area, taking up 80.4% of the total area, remained basically unchanged.

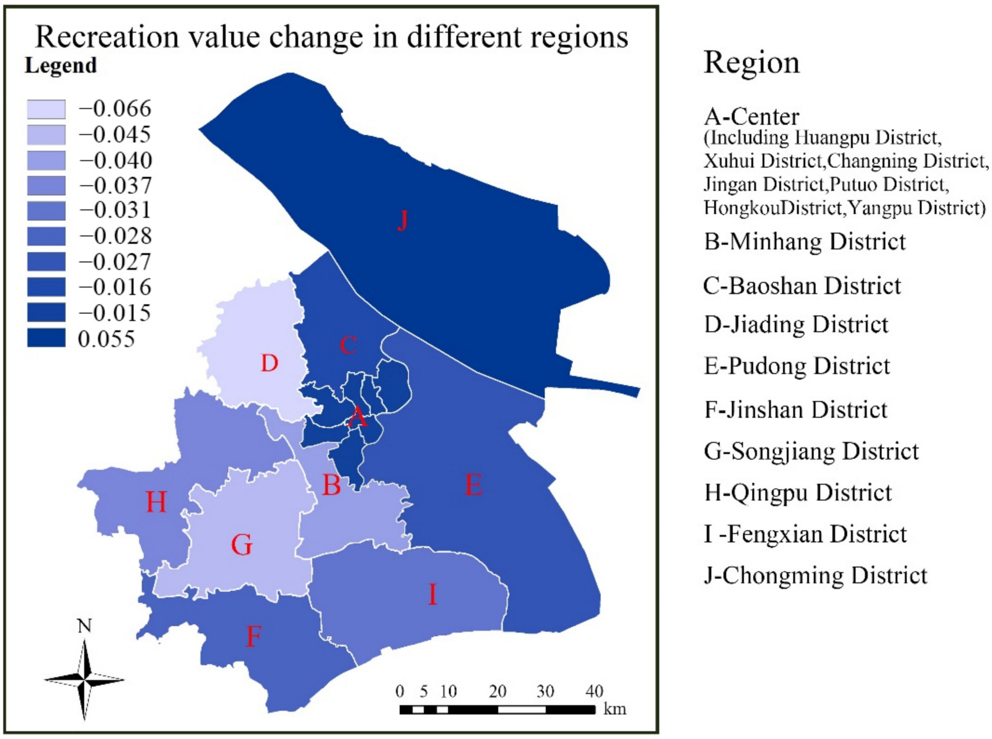

Figure 6. Changes of recreation supply capacity value in different regions of Shanghai from 2008 to 2018.

In terms of spatial distribution, the areas with increased recreation supply are mainly concentrated in the urban center and the outer areas of Shanghai, while areas with decreased recreation supply are mainly located around the outer ring of Shanghai, especially in the northwest. From the perspective of administrative regions, among the areas with increased recreation supply, 49.6% were located in Chongming District, while areas with decreased recreation supply were mainly concentrated in Jiading District, Pudong District and Songjiang District, accounting for 49.7% of all the declining area (Table 4). According to the change of recreation supply in each region, Jiading District experienced the largest decline with the proportion of declining area up to 31.8% during 2008–2018, followed by the Central District of Shanghai (including Huangpu District, Xuhui District, Changning District, Jing'an District, Putuo District, Hongkou District, and Yangpu District) and Minhang District, with a decrease of 23.0% and 20.8%, respectively. Recreation value rose in Chongming District with an area of 300.5 km^2, most of which were distributed in the periphery, occupying 13.3% of the entire area (Figure 7).

Table 4. Statistical table of changed area of recreation supply capacity value in different regions of Shanghai (km^2).

Changes	Center	Minhang	Baoshan	Jiading	Pudong	Jinshan	Songjiang	Qingpu	Fengxian	Chongming
Decrease	66.4	77.7	57.1	146.3	222.5	57.6	100.6	89.6	63.2	63.8
Constant	193.6	264.0	277.1	283.5	1200.4	529.5	476.1	548.0	624.3	2055.8
Increase	28.7	31.2	30.1	30.8	101.2	17.2	27.0	28.9	24.6	314.6
Total	66.4	77.7	57.1	146.3	222.5	57.6	100.6	89.6	63.2	63.8

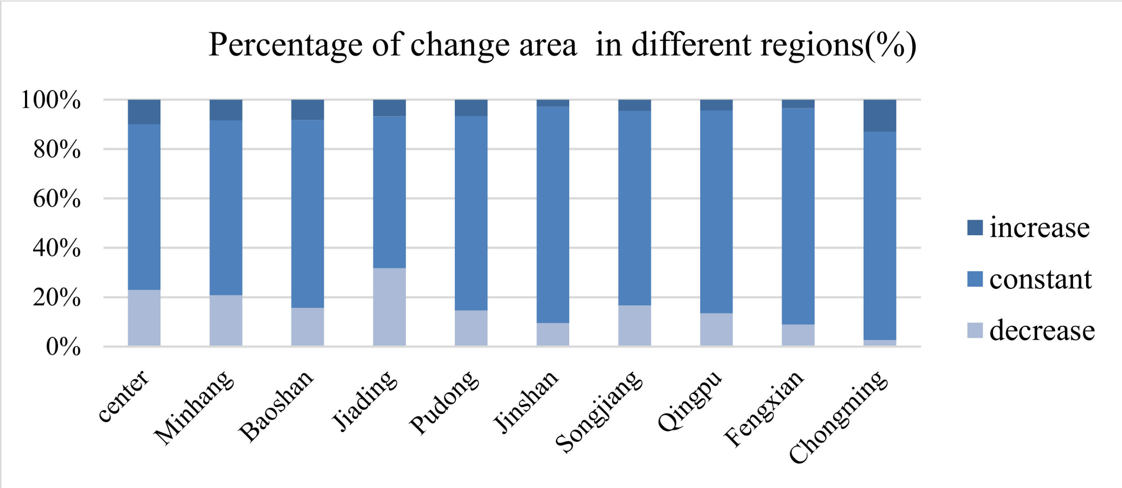

Figure 7. Percentage of changed area of recreation supply capacity in different regions of Shanghai (%).

Based on RP and RO value maps, it can be found in Figure 8 that: (1) The increase or decrease in recreation supply capacity in center region is mainly related to the change in RO. Improved accessibility and increased infrastructure have contributed to the increase in recreation supply capacity in the city center. (2) Different from the city center areas, the increase in recreation supply capacity in Chongming District is mainly related to the increase in recreation potential (RP). In the past ten years, the natural tidal flat wetland and the artificial "Qingcaosha" reservoir on Chongming District have greatly improved its RP. (3) The decline of recreation supply capacity in Jiading district is the largest, which is mainly related to the decline of RP. In the past decade, a large amount of agricultural land has been converted into urban land for urban expansion and development.

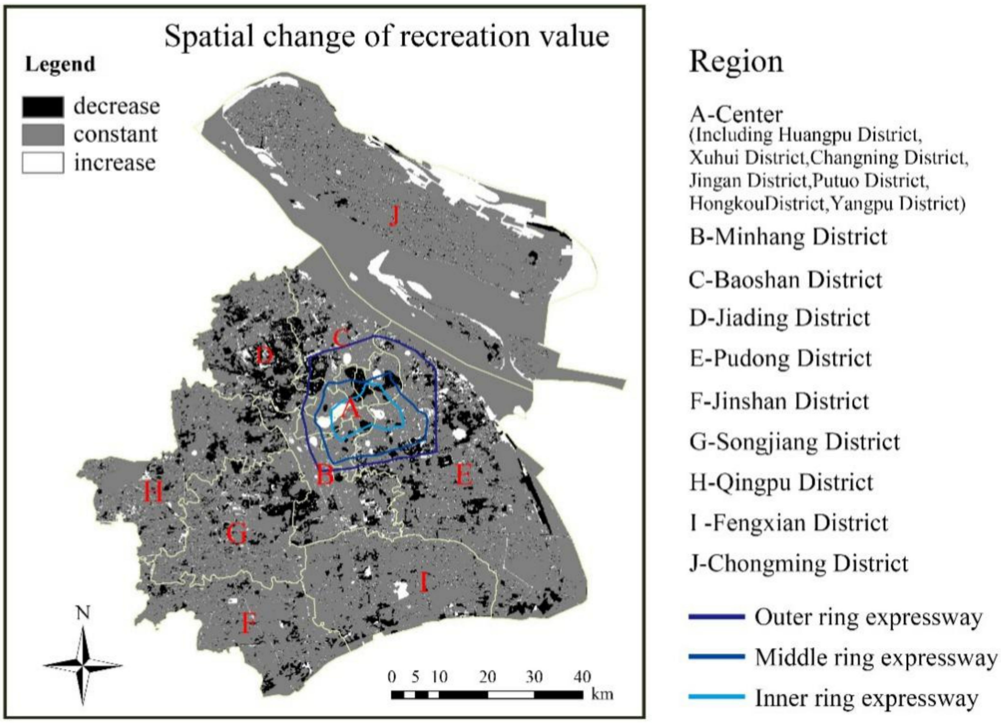

Figure 8. Changes in the spatial distribution of recreation supply capacity value.

4. Discussion

The recreation and tourism industries provide many important benefits and contributions to physical and mental health [52], and provide important opportunities and bonds for managing the interaction between ecosystems and people [53]. We mapped the recreation supply service capacity considering the capacity of the Shanghai land use to provide the service, the accessibility of ecosystems to humans and the infrastructure that is in place to host or guide the visitors. We combined land use data with several web-open data, uses principal component analysis to obtain the factor weights and build an evaluation model considering RP and RO for mapping the recreation in Shanghai. Moreover, based on the mapping results, we obtained the spatial distribution characteristics and changes of leisure supply capacity in Shanghai in 2008 and 2018, and analyzed the causes. In this chapter, we compare the results of this study with previous studies, and propose the potential limitations of this study and the applications of the results in policy and management.

4.1. Comparison of the Results

According to the results, over the past 10 years, the supply of recreational ecosystem services in Shanghai decreased on the whole. At the same time, the recreation supply of the city center—the peri-urban—rural areas showed a "V-shaped gradient". Previous studies also reached similar conclusions. The supply of recreation service in the peri-urban areas of Shanghai was lower than that in the city center and the rural areas, and it was still decreasing over the past decade. This was due to Shanghai's rapid urban expansion, which taken up a large amount of farmland in the peri-urban areas, and the incomplete recreation related infrastructure. Cai et al. discussed the spatial characteristics of ecosystem services in Nanchang City, China under the urban-rural gradient change, and found that along the urban-rural gradient, the recreation opportunity in the main urban area showed a "V-shaped" gradient change [54]. Dobbs et al. evaluated the ES in Bogota and Santiago for a 30-year period with remote sensing data, models, and census data. They found that recreation potential increased in the city center areas and decreased at the peri-urban areas, reflecting increase population and unplanned urban sprawling [55]. Li et al. separated Nanjing city, China into three urbanization categories (developing urban, developed urban, and rural areas) and quantified the status of recreation potential between 2000 and 2010. The results showed that urbanization significantly impacted all ecosystem services, with detected changes in ecosystem services being spatially heterogeneous due to population mobility and urban expansion, and in 2010, recreation potential was highest in rural areas and lowest in urban areas [34].

Meanwhile, results found that the recreation supply capacity of Chongming District (consisting of Chongming Island, Changxing Island, and Hengsha Island, among which Chongming Island is the largest estuarine alluvial island in the world) has increased significantly, mainly due to the increase in natural and man-made wetlands which show great recreational potential. A research investigated the changes in land use and ecosystem services on Dongtan (East Beach of Chongming Island) between 1990 and 2000, and found that the recreation service reduced because of the 71% loss of wetlands/tidal flats caused by large-scale land reclamation projects [56]. It shows that wetlands are very important to recreation services. Researchers also found Shanghai's highest Ocean Health Index (OHI) scores were in the sectors of Coastal Livelihoods and Economies, and Tourism and Recreation, indicating that Shanghai's coastal ecosystems contribute significantly to people's livelihoods and regional economies, while marine recreational areas and related leisure activities add considerably to the quality of life in the region [57].

4.2. Potential Limitations in the Research

This study mapped the distribution of recreation supply capacity value, which assigns to the cultural ecosystem services (CES) category in Shanghai in 2008 and 2018, and found the spatial distribution changes in recreation supply as well as its causes during the past ten years.

However, there are a number of weaknesses which limit the quality of our approach. The shortcomings are due to the several sources of uncertainty, which are related mainly to the highly aggregated information of the land use/cover data set, and missing data impacting the significance of the results. Therefore, an approach which combines high resolution land cover data, and information on actual land management might be advantageous, but as we know, simplifications and reductions in information are a necessary tribute and have to be accepted for achieving a comprehensive picture of complex systems such as landscapes [58]. Furthermore, although we use web-open data such as city POI to represent people's preferences, which makes up for the lack of evaluation system composed of only physical elements, we still lack some more in-depth survey methods, such as questionnaires and interviews. Some scholars believe that such models can be problematic because it is up to the researcher to decide which attributes can be considered to yield the highest recreation value and such expert-based efforts may have limited resonate with the experience and perception of the wider public [21]. Further research is needed on the effects of non-physical factors on recreation value. Recent scientific developments have shown the potential of using social media to collect entertainment activity data. This can be a photo uploaded to an image-sharing website, providing information about the spatial distribution of visited sites and the visitor's appreciation [59]. By comparing our results with those non-physical factors, we can identify which modeling variant fits best for this region and make timely adjustments.

4.3. Land Management Proposals

Our approach to modeling recreation and results of this study can be used to inform land-use policy. From the perspective of land use, the urban and agricultural land accounted for more than 75% of the study area (including the Yangtze River) in 2008 and 2018. Considering such land use, maintaining the rural landscapes alive increases the recreation value of an area. Therefore, promoting agricultural activities and developing rural tourism will improve the recreation value of the study area and make the views from the suburban and rural areas more attractive. Moreover, the recreation or tourism infrastructures could be improved in these areas by developing, for example, rural accommodations [16]. In terms of recreation opportunities, it can be known from the principal component analysis that both in 2008 and 2018, the public transportation facility is an important variable affecting recreation value. In fact, public transportation is generally encouraged for accessibility to country parks in England and Hong Kong [60,61], but nowadays, parks especially those in the suburbs are not connected directly to public transportation networks in Shanghai, which increase the difficulty of usage of public transportation [62]. Otherwise, the importance of recreation infrastructure such as dining spots and service spots has also increased in this decade. Therefore, improvement is needed for the existing urban green spaces and country parks, and the transportation, including establishing road networks and public transportations, along with the recreation infrastructure. In future planning and site selection, priority should also be given to places with good public transportation and other infrastructure.

Meanwhile, although some places may have high recreation value from the perspective of land use, such as the intertidal zone in the north of Chongming Island, they also undertake important ecological conservation functions. The arrival of a large number of tourists may lead to environmental damage [63]. For such sites, building country parks or wetland parks, according to local conditions, in order to exert their recreational functions on the basis of ecological protection, may become a more reasonable choice in the future planning. Furthermore, some places do have high recreational potential but have not received attention or good use for the time being. This may be due to some special reason, such as the noise from highway nearby or the smoke produced in the industries. Ignorance about some areas could also affect recreationists' decisions about visiting. In this case, people can enhance the attractiveness of these venues by improving the surrounding environment for instance by adjusting the surrounding business structure, improving accessibility, and enhancing cultural promotion.

5. Conclusions

We presented an evaluation model to map recreation service supply, one of the cultural ecosystem services based on land use data and other web-open data. Two components were considered in the model, including RP and RO, after conducting a literature review. The main conclusions are as follows.

(1) In 2008 and 2018, the supply of recreation service in Shanghai was spatially heterogeneous, with a "V-shaped" gradient along the urban center and suburb.
(2) Compared with 2008, the supply of recreational ecosystem services in Shanghai decreased overall in 2018 due to rapid urban expansion.
(3) The supply of recreation service in the peri-urban areas was lower than that in the city center and the rural areas, and was decreasing. This was mainly because a large number of farmland and green space disappeared in the process of urbanization. At the same time, because of the incomplete infrastructure in the suburban areas, recreation opportunities cannot be promoted.

In conclusion, the recreation service supply in Shanghai has the problem of spatial inequity. The provision in peri-urban areas is significantly lower than in other areas, to the detriment of the physical and mental health and well-being of the local population. In future urban planning, natural areas in suburban areas should be increased, while other non-natural infrastructure related to recreation can be added to promote spatial equity in the provision of recreation services. We believe that mapping a city's multi-temporal recreation service supply can help to understand the spatial distribution changes. The results can be compared with current policies as well as providing guidance for future development.

Author Contributions: Conceptualization, S.L. and Y.F.; methodology, S.L., P.S., Y.H. and L.J.; software, Y.H.; validation, Y.H.; formal analysis, Y.H.; investigation, Y.H.; resources, S.L.; data curation, Y.H.; writing—original draft preparation, Y.H. and P.S.; writing—review and editing, S.L., P.S., Y.H. and L.J.; visualization, Y.H.; supervision, S.L. and Y.F.; project administration, S.L. and Y.F.; funding acquisition, S.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China, grant number 52178050, and the Shanghai Tongji Urban Planning and Design Institute Co., LTD & China Intelligent Urbanization Co-creation Center for High Density Region, grant number KY-2022-YB-A04.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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