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Spatial Distribution and Accessibility Evaluation of National Water Parks in China

Chenming Zhang [1,*], Bei He [2], Wei Li [3,*] and Chunyang Guo [4]

[1] College of Architecture, North China University of Water Resources and Electric Power, Zhengzhou 450046, China
[2] School of Construction Management and Real Estate, Henan University of Economics and Law, Zhengzhou 450046, China
[3] School of Art and Design, Zhengzhou University of Aeronautics, Zhengzhou 450046, China
[4] School of Tourism Management, Henan Finance University, Zhengzhou 451464, China
[*] Correspondence: zhangchenming@ncwu.edu.cn (C.Z.); lw1990@zua.edu.cn (W.L.)

Abstract: A water park is a nature-based site along a river or water management project that plays a vital role in protecting the local ecological system and providing water recreation, making it an essential component of China's ecological and ecotourism security strategy. This study sought to portray the distribution of China's 878 National Water Parks (NWPs) and to visualize the pattern of accessibility for NWP resources by the gravity-2SFCA method. The investigation produced the following findings: (1) The national-scale pattern of ecotourism and water recreation can be revealed by the distribution of NWPs, which were concentrated on the eastern side of the "Hu Line" but were dispersed on the western side. (2) NWPs can function as detectors of various endowment and management modes of basin-scaled water resources through the relationship between different categories of NWPs and their locations, which can provide guidance for regional planners. (3) The accessibility of NWPs is an effective indicator for revealing spatial disparity between the supply of NWP resources and the population distribution. Then, the general NWP development strategy can be made based on a hot-spot visualization analysis of accessibility patterns.

Keywords: national water park; spatial pattern; accessibility; exploratory spatial data analysis

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1. Introduction

Globally severe hydrological extremes, such as floods and droughts, occur frequently across the globe [1,2]. Water management projects, such as dams, reservoirs, and irrigation canals, are essential for flood control, drought relief, hydropower generation, water resource protection, and soil conservation [3,4].

Wang et al. [3] and Xu et al. [4] found that attaining the high standards required for efficient water management is particularly difficult for single-purpose water conservation projects, prompting the development of multi-purpose projects. In addition to the conventional functions, nature conservation and sightseeing become essential components in the development of multipurpose projects, demonstrating a significant potential for boosting local economies [5]. Therefore, many water conservation projects, such as the Aswan Dam in Egypt, the Three Gorges Dam in China, and the Tennessee Valley Authority in the United States, have been adapted for ecotourism and recreation [6,7].

From the perspective of ecosystem services [8], the aforementioned water facilities provide a variety of ecological and socioeconomic attributes that fall under three categories of services (provisioning services, regulation and maintenance services, and cultural services) [8,9]. The provisioning services primarily include "hydropower supplying" and "water for stock" (drinking and non-drinking water), which generate substantial and direct economic benefits. The regulation and maintenance services consist primarily of the "maintaining populations and habitats" service, the "flood protection" service, and the "erosion prevention" service [8,9], the value of which rise as water management is improved. Four sub-services comprise the cultural services: amenity, recreation, education and research, and spiritual and aesthetic. The subservices of water amenity are the overall quality, experience, and natural values provided by the existence of a lake [10]. The sub-services of water recreation make possible water-based activities such as leisure boating, sightseeing, swimming, recreational angling, and sport fishing [11,12]. The water education and research sub-services enable the general public to comprehend the science and engineering of water [13]. The spiritual and artistic sub-services consist of aesthetic values, a sense of place, cultural heritage values, and other immaterial attributes [14]. In addition, ecotourism, a result of such water facilities, has been found to be advantageous for poverty alleviation, job creation, and market promotion [15], thereby promoting the sustainable development of the local economy and society.

The National Water Parks (NWP) system is China's strategy for enhancing the ecological and socioeconomic attributes of man-made water facilities. China has constructed a large number of water conservation facilities, accounting for nearly half of the world's dams, 20 percent of global hydropower generation, and 21 percent of the world's irrigated area to address the problems of severe water scarcity and extensive flood threats [16]. Many of them feature breathtaking landscapes, attractive surroundings, and cultural and historical sites, which provide a huge space for the development of NWPs.

Moreover, the NWP system follows top-down management from the Ministry of Water Resources to local government. In the public documents of the Ministry of Water Resources, NWP can be defined as a scenic location constructed around a water body or water management project with sufficient environmental capacity and landscape resources to meet the needs of ecological protection, ecotourism, recreation, cultural promotion, and educational activities [17,18]. Typically, NWP integrates diverse landscapes related to hydrology, geography, astronomy, biology, engineering, and humans, thereby performing six primary functions, including maintaining water engineering projects, protecting water resources, enhancing the water environment, restoring water ecology, promoting water culture, and developing water economy.

From an academic perspective, the NWP system in China is very similar to the Protected River System (PRS) or National Wild and Scenic River System (NWSRS) in the United States [19]. These systems play a significant role in the efficacy and effectiveness of ecosystem and biodiversity conservation, attracting interdisciplinary research interest [20–22]. The distribution pattern of NWPs is typically a function of ecoregions, which are influenced by the interaction of natural and human factors such as hydrologic conditions, unique ecosystems, water administrative management policy, and urbanization level [23–25]. From the perspectives of ecology and water-related professions, ecological footprint, ecosystem services, and their evolutionary processes are essential to waterfront management, which can direct ecology restoration and ecological flow allocation [26–31]. According to tourism studies, the greatest concern is how to accomplish sustainable development in the case of NWPs, given the increase in the number of tourists and the overloading of environmental carrying capacity [32–34]. The specific issues are water tourism development, aquatic heritage protection, tourist behavior, and the perception of scenic imagery [35–38]. In addition, intersectional studies between NWPs and other land-protected scenic areas have become a trending topic [39,40]. Unlike other land-based protected scenic areas, NWPs make extensive use of rivers, shorelines, and water management facilities, where artificial projects are permitted to ensure effective flood control and drought resistance. Therefore, NWPs require a unique range of management techniques and are more closely linked to economic and social activities than other types of natural reserves [41,42].

The following is a summary of the limitations of previous research.

(1) The multi-scaled portrait of water facilities for ecotourism and recreation has not been illustrated. There are various research values at various scales. The watershed scale is suitable for comprehending the relationship between water park categories and locations [43]. The national dimension is more suitable for revealing the spatial

disparities between water parks, traffic networks, populations, and cities. However, multi-scale investigations have received considerably less attention.

(2) The water facilities for ecotourism and recreation have not been considered simultaneously as "sources" and "sinks". The majority of previous studies [44,45] regarded water-based scenic locations as tourist destinations, i.e., a "sink" that attracts visitors. Few studies have examined the dialectical relationship between "sources" and "sinks" in both directions, and scenic areas have been identified as water resource "sources".

(3) The interaction between various locations of supply (water ecotourism and recreation resources) and population demands has not yet been investigated. Regional studies have traditionally calculated the per capita value of resources using the so-called "container approach". For this method, the study area is divided into distinct spatial "containers" with specific boundaries, and the per capita resources accessed in each container are estimated without taking visitor movement across the boundary [46] into account. In actuality, people are not restricted to visiting the water park closest to them, and each water park may receive visitors from various neighborhoods. The many-to-many relationship necessitates a more thorough analysis of spatial accessibility.

(4) The current accessibility evaluation for water parks is insufficient to support the coordinated sustainable development of WNPs with traffic, population, and cities. On the one hand, case studies for accessibility have not included the visualization and agglomerative patterns of hotspots as a further analysis pertinent to NWPs planning. On the other hand, there is a lack of comparative studies and general regulations for various regions or nations that incorporate accessibility into the ecological and socioeconomic values of water parks.

Consequently, the study seeks to overcome the aforementioned limitations and accomplish the innovative objectives: (1) Depict the spatial pattern of water ecotourism and recreation in China by combining ecological and geographic perspectives at both the national and basin scales. (2) Evaluate the prospective NWPs resources accessed per capita, taking trans-regional activities into account, so that NWP facilities serve not only the cities in which they are zoned, but also neighboring cities. In addition, the accessibility algorithm incorporates the gravity function to simulate the distance attenuation effect. (3) Visualize the accessibility of NWPs resources using a comprehensive national database, and quantitatively disclose the hot-spot and cold-spot patterns of accessibility values using an additional ESDA (Exploring Spatial Data Analysis) method, which will have more application for NWP strategies. (4) Derive general conclusions from Chinese experience to regulate the layout and development of NWPs that are compatible with sustainability principles such as comprehensive resource utilization and enhancement of resource utilization capacity for traditional practices [47].

The remainder of the paper is structured as shown in Figure 1: first, a database of NWPs, population, traffic networks, and cities is compiled. At various dimensions, the spatial patterns of NWPs are portrayed. In the subsequent segment, the accessibility of NWPs and its spatial agglomeration pattern are evaluated and depicted. The report concludes with a discussion and generalizations of the results applicable to NWP strategies.

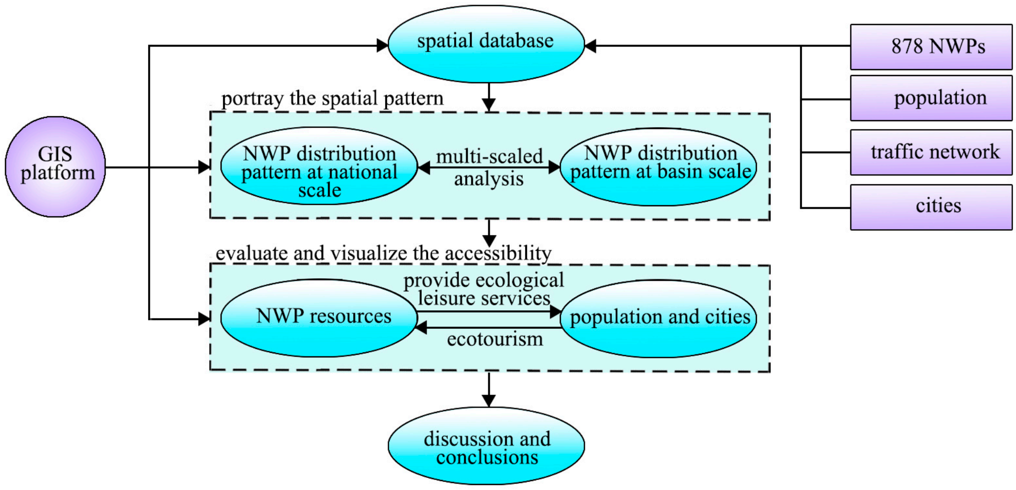


Figure 1. Flow chart of the whole research.

2. Data Process and Research Methods

2.1. Data Process

This study includes 878 NWPs, which can be categorized into six groups, namely, 391 reservoir type (RES), 39 wetland type (WLD), 193 natural river and lake type (NRL), 194 urban river and lake type (URL), 24 irrigation area type (IRA), and 37 water and soil conservation area type (WSC) [48]. The locations of the 878 NWPs, as provided by China's Ministry of Water Resources, are depicted in Figure 2. LandScan (https://landscan.ornl.gov/, (accessed on 20 December 2022)) provides the population amount in the year 2021 (Figure 3a). Baidu Maps is used to gather the transportation network (Figure 3b). It is designated that the speed on the highway is 100 km/h, that of national roads is 80 km/h, and that of provincial roads is 60 km/h based on the difference in travelling speeds between road types [49].

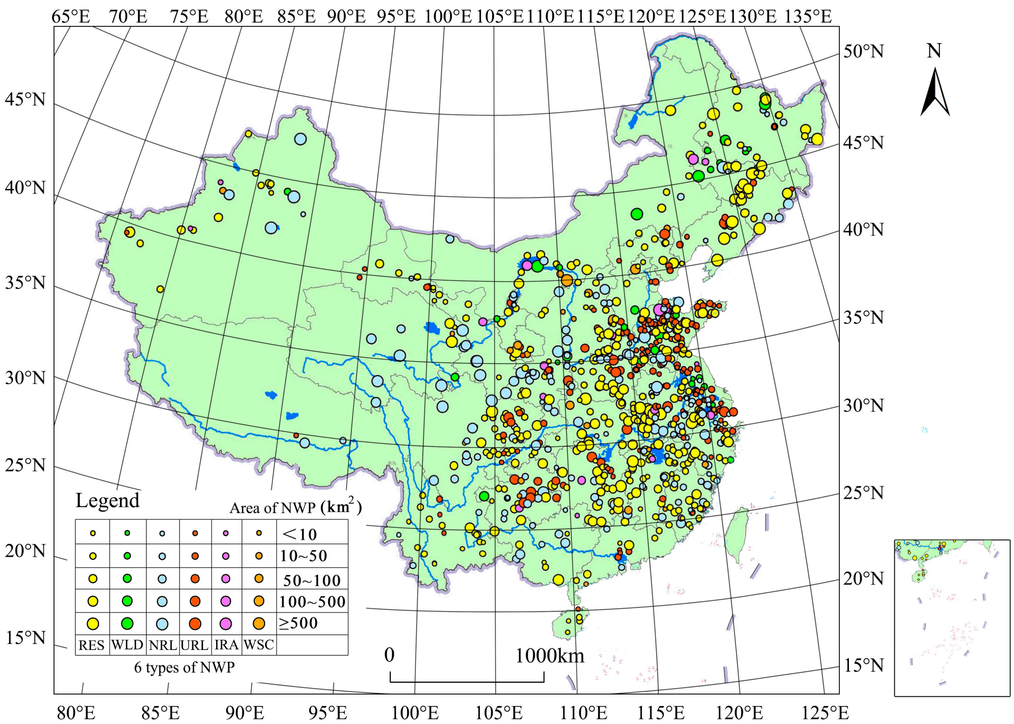


Figure 2. The types, scale, and distribution of 878 NWPs.

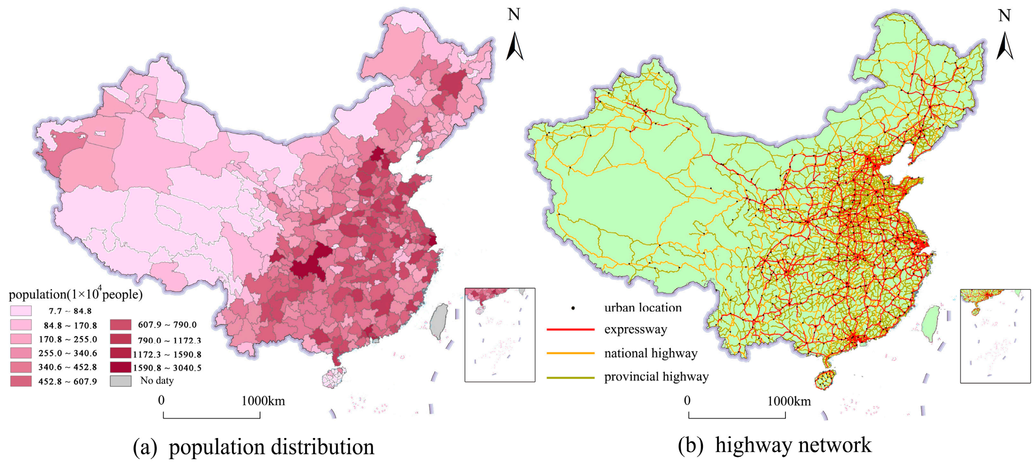


Figure 3. The visualization of the basic data (**a**) is the distribution of population in 2021, (**b**) is the highway network in China.

2.2. Research Methods

To analyze the spatial distribution pattern and accessibility of NWPs, the standard deviation ellipse, kernel density, enhanced two-step floating catchment area (2SFCA), and exploratory spatial data analysis (ESDA) are presented. In data processing, ArcGIS, Jupyter notebook, and Geoda are utilized.

2.2.1. Kernel Density

Kernel density estimation (KDE) is used to draw the data map of the density distribution of dots (The dots in this research are NWPs). It is crucial for spatial analysis to visualize where the density is high and where the density is low if the dots are distributed unevenly. The basic idea of the KDE is that the spatial information of the dots input is spread on a plane, outputting a raster image with kernel density of each pixel value measured. The kernel density of pixel x can be calculated from the dots within a certain range around pixel x using the formula described as follows [50]:

$$f(x) = \frac{1}{nh^2}\sum_{i=1}^{n} k\left(\frac{d(x,i)}{h}\right) \tag{1}$$

$f(x)$ is the kernel density of pixel x, h is the bandwidth (fixed radius), which influences the smoothness of the kernel density distribution, n is the number of NWP points within the bandwidth range, $d(x,i)$ is the distance between the center point of the pixel x and the NWP point i within the bandwidth, and k is the kernel function, which determines the density-reduction process as the distance from the NWP points increases. The KDE can be understood to be the result of spatial probability accumulation resulting from summation [51].

2.2.2. Standard Deviation Ellipse

The standard deviation (SD) ellipse method is a common way to reveal the overall directional characteristic and the extension pattern of dots. A particular SD ellipse can be drawn by a set of sample dots. The center of the SD ellipse is determined by the average location of the dots; the long axis direction of the SD ellipse orients the main distribution trends of the dots; the lengths of the long axis and short axis of the SD ellipse represent the maximum and minimum extension of the dots in corresponding directions, respectively. The SD ellipse is more oblate the more significant directionality the sample dots present. Basic parameters of the SD ellipse include the center coordinate, standard deviations of the x- and y-axes, and rotation angle. The formula for calculation is as follows [52]:

$$x^*_i = x_i - \overline{X}; \quad y^*_i = y_i - \overline{Y} \tag{2}$$

$$\tan\theta = \frac{(\sum_{i=1}^{n} w_i^2 {x^*}_i^2 - \sum_{i=1}^{n} w_i^2 {y^*}_i^2) + \sqrt{(\sum_{i=1}^{n} w_i^2 {x^*}_i^2 - \sum_{i=1}^{n} w_i^2 {y^*}_i^2)^2 + 4(\sum_{i=1}^{n} w_i^2 {x^*}_i^2 {y^*}_i^2)^2}}{2\sum_{i=1}^{n} w_i^2 {x^*}_i {y^*}_i} \tag{3}$$

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n} (w_i {x^*}_i \cos\theta - w_i {y^*}_i \sin\theta)^2}{\sum_{i=1}^{n} {w_i}^2}}\ ;\ \sigma_y = \sqrt{\frac{\sum_{i=1}^{n} (w_i {x^*}_i \sin\theta - w_i {y^*}_i \cos\theta)^2}{\sum_{i=1}^{n} {w_i}^2}} \tag{4}$$

In the formula, $(\overline{X}, \overline{Y})$ is the coordinate of gravity point of NWPs in the river basin and (x_i, y_i), $({x^*}_i, {y^*}_i)$ are the absolute coordinates and relative coordinates of the ith NWP, respectively. θ is the angle of rotation of the ellipse (due north is 0 degrees, clockwise rotation). w_i is the weight by the areas, and σ_x and σ_y are the standard deviations along the x axis and y axis, respectively.

2.2.3. Distance-Decay Improved Two-Step Floating Catchment Area

The two-step floating catchment area (2SFCA) is a GIS method to evaluate the accessibility indicator which measures how many resources can be obtained per capita in a certain area. The model basically assumes the following: (1) That there exists some points supplying resources and some areas need to be supplied; (2) each point allocates its resources to the areas around it within a certain distance (searching threshold), and the quantity of allocation is depend on both the population size and the distance; (3) each area can obtain resources from the points within the searching threshold; and (4) the total supply of resources from the same resource point is limited to its capacity. Then, the accessibility of the resource for each area can be computed by two steps of searching as follows [53–55]:

Scanning for city centers surrounding NWPs. Count the number of city sites within each NWP's criterion and compute the supply-to-population ratio at each spatial unit.

$$R_j = \frac{S_j}{\sum_{\{d_{ij} \le d_0\}} w(d_{ij}) D_i} \tag{5}$$

In the formula above, R_j is the ratio of supply to population at the supply point j, S_j is supply scale at the supply point j represented by NWP area, D_i is the total population of city i, d_0 is the searching threshold, and d_{ij} is the time cost from city point i to supply point j.

Searching NWPs around city points as centers. Spatial accumulation of R_j at point j is computed.

$$A_i = \sum_{\{d_{ij} \le d_0\}} w(d_{ij}) R_j \tag{6}$$

where A_i is the accessibility of NWP resources at city i. Obviously, the essence of A_i is the opportunity for accumulation of "supply/population ratio" at location i, which refers to the relative ease by which a given NWP can be reached from a given location. The higher A_i is, the more accessible location i is, and vice versa.

A distance-decay function $w\,(x)$ is introduced into the original form of 2SFCA and can be written as Formula (7), aiming to simulate the distance attenuation effect from the supplying points (NWPs) to the cities.

$$w(d_{ij}) = \begin{cases} 0 & d_{ij} > d_0 \\ \frac{1}{{d_{ij}}^2} & d_{ij} \le d_0 \end{cases} \tag{7}$$

This gravity function benefits from the advantages of concision and accuracy, and proved to be more accordant with practice. In addition, the downtown location rather than the centroid of the administrative district is selected as the city center.

2.2.4. Exploratory Spatial Data Analysis (ESDA)

The first law of geography states that "everything is related to everything else, but near things are more related to each other" [56]. The ESDA method reveals to what degree the near things are related to each other. More academically, the ESDA is typically employed for measuring and mapping the properties or spatial patterns of geography objects, identifying the spatial clustering of social and economic phenomenon, and detecting the spatial differences and correlation degree of the research area. The foundation of ESDA is the spatial autocorrelation analysis based on a combination of graphic and statistical data, which consists of two methods: global spatial autocorrelation analysis and local spatial autocorrelation analysis [57].

(1) Global Spatial Autocorrelation

Global spatial autocorrelation describes the spatial features throughout the study area. Moran's I index is a measurement index of global spatial autocorrelation, which can be calculated as follows:

$$\text{Moran's } I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\overline{x})(x_j-\overline{x})}{(\sum_{j=1}^{n}\sum_{j=1}^{n} w_{ij})\sum_{i=1}^{n}(x_i-\overline{x})^2}$$
$$w_{ij} = \begin{cases} 1 & when\ the\ region\ i\ and\ the\ region\ j\ are\ connected \\ 0 & when\ the\ region\ i\ and\ the\ region\ j\ are\ not\ connected \end{cases} \quad (8)$$

x_i and x_j are the values of accessibility calculated by Formula (6) at region i and region j, respectively. x is the average of x_i. w_{ij} is the spatial weights matrix. The value of Moran's I is within the scope of $[-1, 1]$. When Moran's $I > 0$, it represents positive spatial correlation. When Moran's $I < 0$, negative spatial correlation is represented. When Moran's $I = 0$, a lack of correlation is represented.

(2) Local Spatial Autocorrelation

The global Moran's I reveals only the overall spatial dependence of geographical phenomena and is incapable of comparing local spatial differences. Consequently, a local spatial autocorrelation analysis is required [58]. Local indicators of spatial association (LISA) are utilized to indicate the dissimilarity between a particular location and its environs. The ith region's LISA index is computed as follows:

$$I_i = \frac{x_i - \overline{x}}{S^2}\sum_{j}^{n} w_{ij}(x_j - \overline{x}) \quad (9)$$

x_i, x_j, x, and w_{ij} are the same parameters mentioned above for the global spatial autocorrelation. S^2 is the discrete variance of x_i. At a given significance level, a LISA aggregation map is created, combining the LISA significance level with the scatter plot, in which the "hot spot" and the "cold spot" can be identified. The LISA figure can be divided into four significant types: ① High–high aggregation type: $I_{LISA} > 0$, the accessibility level of area i and its adjacent areas are both higher than the average level; ② Low–low agglomeration type: $I_{LISA} > 0$, the accessibility level of area i and its adjacent areas are both lower than the average level; ③ High–low aggregation type: $I_{LISA} < 0$, the accessibility level of area i is higher than the average level while its adjacent areas are lower than the average; ④ Low–high aggregation type: $I_{LISA} < 0$, the accessibility level of area i is lower than the average level while its adjacent areas are higher than the average.

3. Patterns of Spatial Distribution of NWPs

3.1. Distribution Pattern of National-Scale NWPs

Figure 4 depicts the global distribution of each NWP type, revealing a typical pattern of clustering in the eastern region of the Hu Huanyong Line and scattering in the western region.

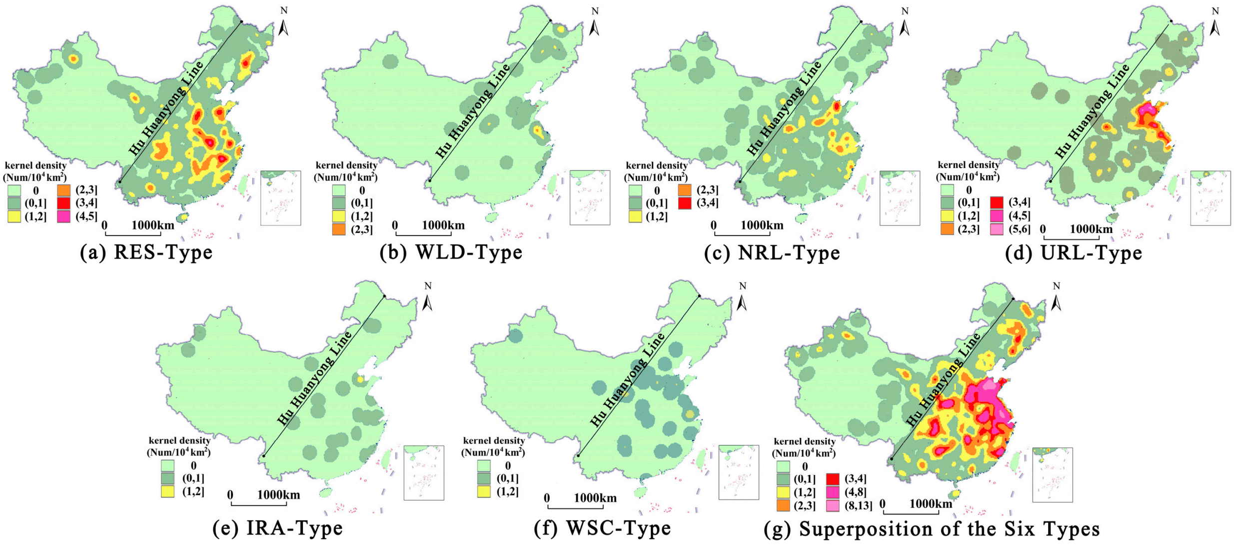


Figure 4. The kernel distribution of each type of NWP.

The kernel density of a particular type of scenic location ranged from 0 to 6/10^4 km^2, whereas the kernel density of each type after superposition ranged from 0 to 13/10^4 km^2 (Figure 4). Low-density areas (0~1 Num/10^4 km^2), medium-density areas (1~2 Num/10^4 km^2), medium-to-high-density areas (2~3 Num/10^4 km^2), and high-density areas (>3 Num/10^4 km^2) were categorized to disclose the distribution pattern of NWP hotspots. There were 391 RES-Type NWPs with a maximum kernel density of 4.25/10^4 km^2 (see Figure 4a). Medium-high-density and high-density areas were dispersed, predominantly along the eastern coast, in six central provinces, and in portions of eastern Sichuan. There were 194 URL-Type NWPs (see Figure 4d), and the maximum kernel density was 5.52/10^4 km^2, with medium-high-density areas and high-density areas concentrated in Shandong province and extending into patches from Jiangsu province to the Yangtze River Delta; high-density areas also exist in a single point in Xi'an. Figure 4c depicts 193 NRL-Type NWPs with a maximal kernel density of 3.67/10^4 km^2. Near Binzhou in Shandong province, a solitary high-density zone was identified, while the medium-high-density regions were sporadically distributed and relatively small. The IRA-Type (see Figure 4e) has 24 NWP spots, whereas the WLD-Type (see Figure 4b) and WSC-Type (see Figure 4f) have 39 and 37 NWP spots, respectively. Generally, the kernel density of these scenic areas is below 1/10^4 km^2, signifying a small number. There were few areas of medium-high- and high-density aggregation, and low-density areas were dispersed across the landscape, with more in the east and fewer in the west.

Based on the superposition of the six types on the integrated map (Figure 4g), the kernel density was higher in the east and lower in the west. Multiple aspects of the ecological and human environment determined the distribution of NWPs. The emergence of medium-high- or high-density areas necessitated the following conditions: the areas must be surrounded by sufficient water resources, partially exploited through water conservation projects, and have sufficient water to fulfil local industrial, agricultural, or urban needs. In addition, the scenic clusters may be surrounded by a dense population, communities, a transit system, and an abundance of water conservancy heritages (such as the area surrounding the Beijing–Hangzhou Grand Canal). If the aforementioned conditions are met, the water value chain can be enhanced because water resources can be converted into water landscape resources. The strong similarity between the macroscopic distribution of NWPs and the Hu Huangyong Line reveals the spatial–temporal connections between natural geographical elements and human geographic components in China.

3.2. Pattern of NWP Distribution at the Basin Scale

Using watersheds as the analyzing unit, the relationships between NWPs and the main rivers and streams were revealed based on the waters and shorelines. To illustrate the distribution and expansion direction of NWPs at the watershed scale, standard deviation ellipses for NWPs were generated for each of the nine watersheds (Figure 5) and the ratio of long to short semiaxes of each ellipse is shown in Table 1. The Yangtze River, Yellow River, and Huai River basins accounted for 63.4% of the total number of NWPs, totaling 557 (Figure 5 and Table 1). These are the overarching characteristics: (1) The direction of each standard deviation's long axis is considered. In accordance with river trends on a watershed scale, ellipses are present. (2) The ratio of the long axis to the short axis ranges from 1 to 3, with a mean of 1.99. Thus, a strip distribution characteristic exists at the scale of a basin; the longitudinal dispersion degree is roughly double that of the width. (3) According to the degree of strip extension, WLD type > URL type > NRL type > WSC type > IRA type > RES type. The difference in deviation of ellipse shape between different NWP types can be explained as follows: WLD-Type NWPs were more prevalent in the intermediate and lower river reaches. They differed considerably from other types in terms of their standard deviation ellipse, and a few of these NWPs were slightly inconsistent with the watershed's overall direction. URL-Type NWPs were located in the central cities of the watershed, and these cities constituted the axis of economic development for the watershed, causing the standard deviation ellipse to be long and skinny. The NRL-Type NWPs were typically situated on either side of the major rivers, and their standard deviation ellipse closely resembled the watershed's overall shape. WSC and IRA-Type NWPs were uncommon, and no discernible geographic pattern was observed. RES-Type NWPs were frequently built on small- to medium-sized reservoirs, which were common and widely distributed in tributaries. In contrast, only a few of the large reservoirs located in the principal streams have been developed as NWPs, as their primary purpose was water engineering rather than landscape. Consequently, RES-Type standard deviation ellipses were relatively round compared to those of other varieties.

Table 1. Ratio of long- to short-half axis of each standard deviational ellipse.

	RES-Type	WLD-Type	NRL-Type	URL-Type	IRA-Type	WSC-Type	Superposition of the Six Types
Yangtze River Basin	1.85 (151)	12.02 (4)	1.99 (66)	2.84 (51)	2.23 (7)	1.91 (13)	1.99 (292)
Yellow River Basin	1.59 (39)	1.48 (9)	3.16 (43)	2.22 (17)	1.99 (5)	2.56 (10)	2.02 (123)
Huai River Basin	2.59 (43)	1.86 (8)	2.13 (16)	1.60 (68)	/ (2)	1.61 (5)	1.93 (142)
Hai River Basin	2.93 (26)	2.23 (3)	3.07 (8)	1.87 (23)	/ (2)	2.62 (4)	1.71 (66)
Pearl River Basin	1.93 (26)	/ (0)	2.86 (12)	9.23 (5)	/ (2)	/ (2)	1.98 (47)
Songliao River Basin	1.40 (45)	3.30 (11)	1.13 (12)	2.37 (14)	/ (2)	/ (1)	1.46 (85)
Continental River Basin	3.23 (24)	/ (2)	2.02 (9)	39.28 (4)	/ (2)	/ (1)	2.53 (42)
Southeastern Rivers Basin	2.63 (30)	/ (2)	2.48 (22)	2.09 (10)	/ (2)	/ (1)	2.56 (67)
Southwestern Rivers Basin	1.62 (7)	/ (0)	1.90 (5)	/ (2)	/ (0)	/ (0)	2.69 (14)
Weighted average	2.07	3.41	2.36	3.08	2.13	2.15	1.99

Note that the value in parentheses is the number of NWPs in each watershed, while the symbol "/" indicates that the NWP points in the watershed were too few to form a standard deviation ellipse and did not contribute to the computation of the mean.

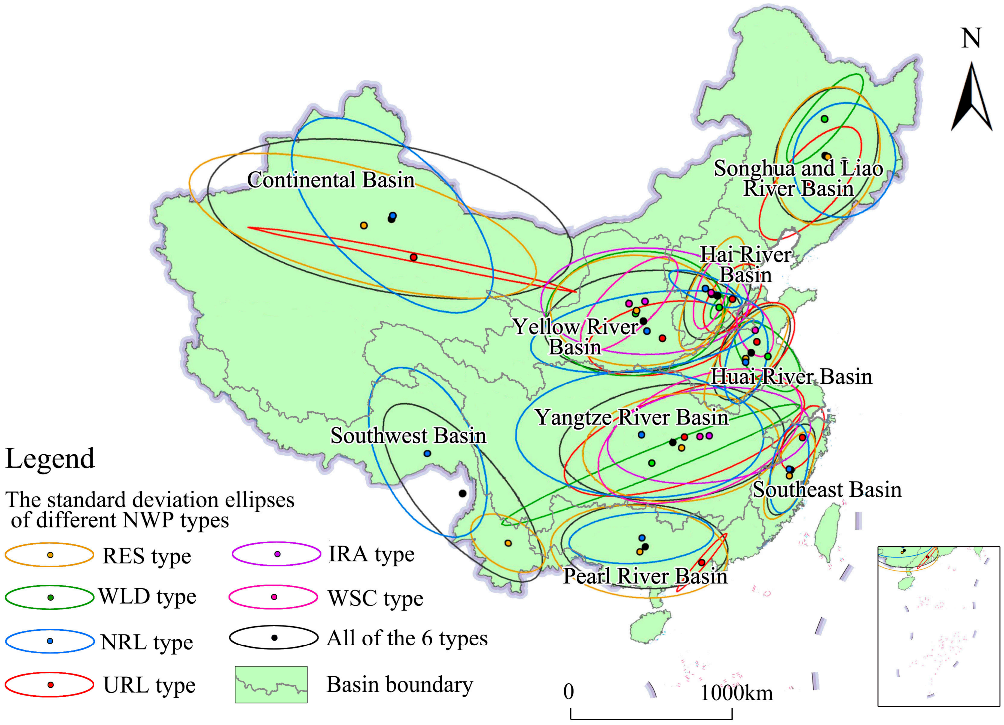
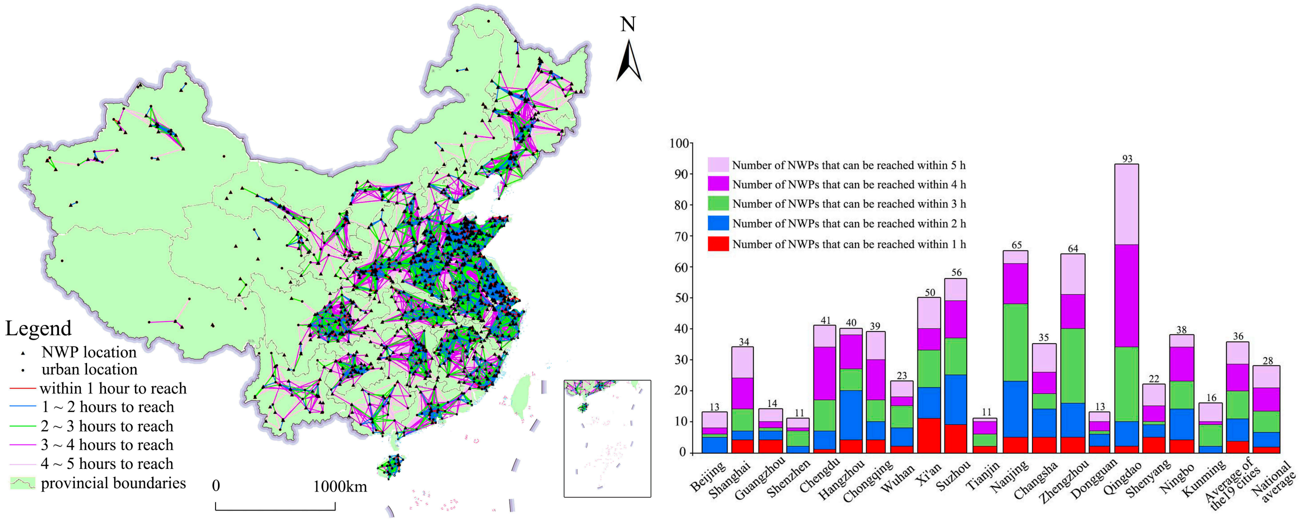


Figure 5. Standard deviational ellipses of NWPs in each basin.

4. Accessibility of NWPs Resources Based on Transportation, Population, and Cities

4.1. Road Network Connecting NWPs and Urban Centres

The study area was divided into 362 spatial districts based on administrative divisions at the national level. The GIS platform was utilized to determine the central location of the major city in each prefecture district. Figure 6a depicts the subsequent establishment of a spatiotemporal connection network between the cities and their accessible NWPs within 5 h. Using each city as a starting point, the quantity of NWPs within the various radiation radii was tallied. Figure 6b exhibits only the number of NWPs that are accessible from the 21 largest cities (first-tier or new first-tier cities) to conserve space.



(a) The temporal network between cities and NWPs (b) Number of NWPs surrounding the main cities

Figure 6. The temporal network and data statistics between cities and NWPs.

The starting and ending sites of each connecting line in the network depicted in Figure 6a were cities and NWPs. The network was primarily concentrated in eastern and central China. Local networks were dense at the provincial level in Shandong, Henan, Anhui, Jiangsu, and Zhejiang, where interprovincial connectivity was robust. In these regions, it was advantageous to have a NWP representative travel across provinces. Due to insufficient road network development in these regions, the local network was sparse in Xinjiang, Tibet, and Qinghai provinces, with some isolated points. Other provinces exhibited the following pattern of group development: a relatively independent sub-network formed within the province, whereas interprovincial connections were quite loose, with spaces consistent with the direction of the administrative boundary.

As demonstrated in Figure 6b: (1) As the radius of radiation expanded, the number of NWPs that radiated grew, with first-tier and new first-tier cities serving as the center. The rate of development was greatest in Qingdao and lowest in Tianjin. (2) There was a statistically significant difference in the number of NWPs that were accessible from the major cities enumerated in Figure 6b. Xi'an had the greatest number of NWPs reachable within a 1 h circle (n = 11), whereas Beijing, Shenzhen, and Kunming had the fewest (n = 0). Qingdao had the most NWPs accessible within a 5 h circle (n = 93), which was 8.5 times greater than Tianjin or Shenzhen, which had the fewest (n = 11). Beijing, Shenzhen, Tianjin, Dongguan, and Kunming had fewer NWPs than the national average, whereas the majority of significant cities had more. In the aforementioned cities, NWPs were not the predominant type of multipurpose water conservation initiatives.

4.2. Mapping the Accessibility of NWPs and Measuring Its Spatial Autocorrelation

The accessibility of NWP resources for each spatial unit was computed and mapped (see Figure 7a,d) based on the spatial–temporal relationship between NWPs and localities depicted in Figure 6. In addition, exploratory spatial data analysis (ESDA) was performed to identify the accessibility value peaks in Figure 7b,e.

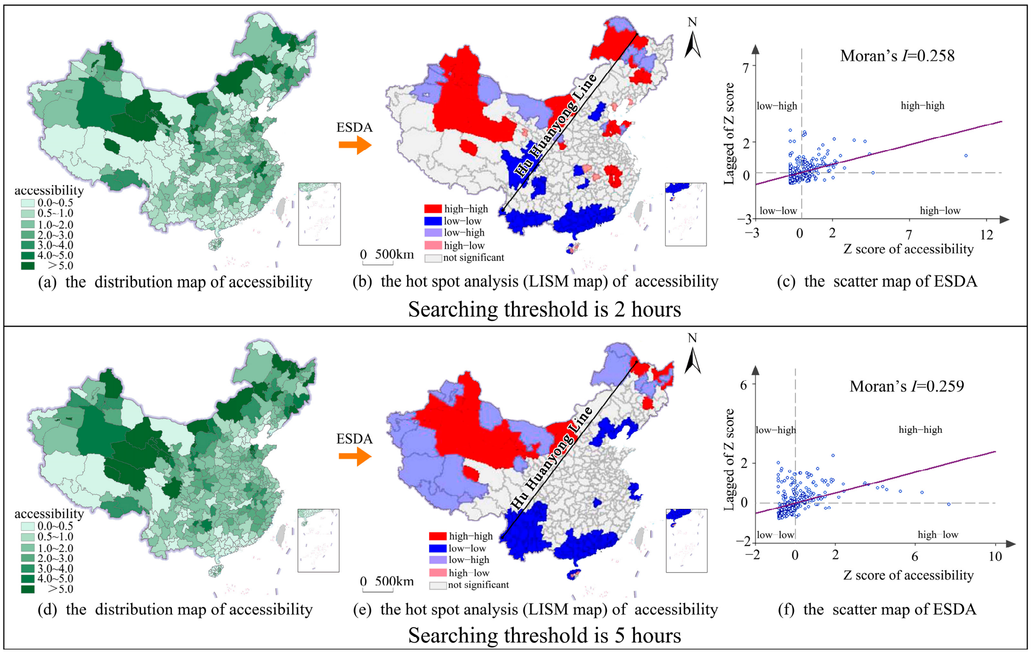


Figure 7. Accessibility of NWPs computed by different service radial thresholds ((**top**): 2 h; (**bottom**): 5 h).

Overall, the accessibility value distribution exhibited a macro pattern of being high in the north and low in the south, which did not correspond to the kernel density distribution of NWPs. The justification will be discussed in the discussion section. With 2 h and 5 h thresholds, the utmost value of accessibility is calculated to be 24.23 and 19.61, respectively.

According to the ESDA results, the values of global Moran's I were 0.258 and 0.259 when the search thresholds were 2 h and 5 h, respectively; both values passed the significance test, indicating that the accessibilities for NWP resources calculated in different trip radii share similar global spatial agglomeration characteristics. Local spatial autocorrelation displays similar characteristics. The districts with high–high clustering in both scenarios were predominantly located in the northwest (Urumqi, Altay, and Korla in Xinjiang, Haixi in Qinghai, and Bayannur and Erdos in Inner Mongolia). In contrast, Beijing, Tianjin, Hebei, Guangdong, and Yunnan made up the majority of the regions with low–low concentration in both scenarios.

There were differences between Figure 7b,e, indicating that the accessibility pattern was sensitive to variations in thresholds for searching. A comparison is made between the hot spot maps visualized by 2 h searching threshold and 5 h searching threshold values.

(1) In the map of 2 h, both the hot spot areas (high–high significance) and cold spot areas (low–low significance) are dispersed. Meanwhile, in the map of 5 h, both the hot and cold spot areas are more connected and agglomerated. Detailed changes of the spatial features can be observed when the searching threshold increased from 2 to 5 h: the high–high agglomeration areas in the northwest extend eastward to Jiuquan, and westward to Aksu; the low–low clustering area surrounding Beijing–Tianjin–Hebei extended north along the Bohai Bay to Dalian; the low–low clustering area in southern Yunnan reached Sichuan.
(2) In the map of 2 h, there exists an intermixed trend between hot spot clusters and cold spot clusters. Meanwhile, in the map of 5 h, there is a spatial separation trend from hot-spot clusters to cold-spot clusters. From the 2 h map to the 5 h map, some local spatial clustered phenomenon disappeared, indicating that high–high or low–low characteristics were no longer significant ($p > 0.05$). For example, Shandong, southern Anhui, northern Jiangxi, and eastern Inner Mongolia experienced the disappearance of significance from high–high areas, while western Sichuan and western Hubei experienced it from low–low areas.
(3) As for the overall spatial differences between the northwest and the southeast, the map of 5 h reveals the overall differences more strongly than that of 2 h. From the 2 h map to the 5 h map, the high–high clustered areas tend to be distributed in the northwest rather than the southeast, whereas the low–low clustered areas present an opposite trend. The boundary zone between high–high clustered areas and low–low clustered areas becomes clearer, with more areas in the central region not being substantially agglomerated. In particular, several new high–high clusters emerged in Xinjiang and Gansu, and a new low–low clustered group emerged around Shanghai.

5. Discussion and Concluding Remarks

5.1. Discussion

5.1.1. Types and Distributions of NWPs

At the national scale, the distribution and development of water parks are frequently influenced by a number of factors, such as natural resources and ecological context, specific transportation locations, and urban, demographic, and socioeconomic factors [59]. Several studies have demonstrated that natural scenic locations are influenced by a variety of physical and cultural geographic factors, exhibiting a pattern of high density in the east and low density in the west along China's Hu Huanyong Line [60,61]. This study revealed that the spatial–temporal interaction between natural and human geographic factors in China contributed to the similar distribution patterns of NWPs. At the basin scale, diverse water management initiatives exhibited distinct distribution patterns affected by different local water resource endowments, which were tightly correlated with urban and regional development. Given that NWPs serve as a link between the natural environment and socioeconomic development, the standard deviation ellipse of NWP distribution can be used as an indicator for measuring the development of resource–population–city integrated systems and as a foundation for optimizing the allocation of water landscape resources.

5.1.2. Spatial Compatibility of NWP Resource and Population

Although the NWP kernel density was greater in the east than in the west, the accessibility of NWP resources was inverted. This indicates a spatial disparity between the total indicators (the kernel density of NWP resources) and per capita indicators (the accessibility of NWP resources). A local LISA (local indicators of hot spot analysis) map of the number of NWPs per capita (Figure 8a) and a local LISA map of the bivariate spatial autocorrelation between NWPs and population (Figure 8b) are compared to illustrate this issue. Figure 8a demonstrates a distribution pattern that closely resembles Figure 6b,e, with a high–high area clustered in the northwest and low concentrated in Beijing–Tianjin–Hebei, southern China, and the southwest. However, Figure 8b displays a more distinct pattern than Figure 6b,e, with the east coast and the west coast exhibiting high–high concentrations and low–low concentrations, respectively, in accordance with the general trend of high scenic density in the east and low scenic density in the west. The distribution of NWPs and populations indicates a match for the total quantity but a mismatch for the per capita volume, as revealed by these findings. From an algorithmic standpoint, the 2SFCA method measures the amount of a cumulative per capita resource accessed by individuals with border-unrestricted activities [62]. In the east of the Hu Huanyong Line, population concentrations were relatively stronger than those of NWPs, resulting in low–low areas in the corresponding position in Figure 6a–c, and high–high and high–low areas in the corresponding position in Figure 7d; in the west of the Hu Huanyong Line, population concentrations were relatively stronger than those of NWPs, resulting in high–high or low–high areas in the corresponding positions in Figure 7d.

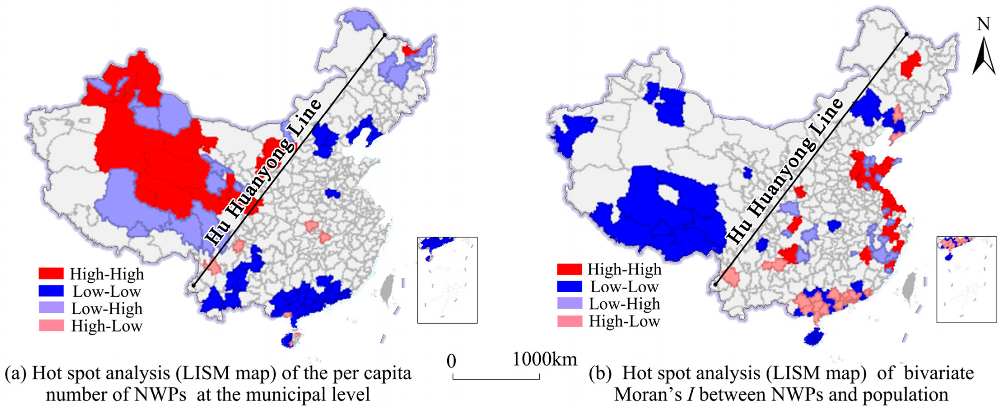


Figure 8. Comparison of the hot-spot maps between different indicators.

5.1.3. The Influence of the Search Threshold on the Availability of NWP Resources

Searching thresholds have significant impacts on the spatial pattern of accessibility values [63], and a lower threshold is associated with a more pronounced spatial variation of the measured results. A higher threshold results into a spatial trend that is more continuous [64]. Our results were consistent with the aforementioned pattern. The accessibility calculated with a 2 h travel radius searching threshold was closer to a local indicator, which is appropriate for simulating short-distance travelling behavior. This finding facilitates the identification of local variations in accessibility values. Accessibility calculated with a 5 h travel radius searching threshold corresponded more closely to a global indicator, making it suitable for simulating long-distance travel and revealing a stronger clustering pattern, with a concentration of high–high accessibility in northwest China and low–low accessibility in south China and southwest China.

5.1.4. The Limitations

This study has several limitations. First, the 2SFCA method can still be improved further. Depending on the resource quantity, the servicing scope of NWPs varies, as does the maximum travel radius of individuals in cities with differing degrees of economic development. Future studies are encouraged to integrate a variable searching threshold into the 2SFCA algorithm. Second, the time–space network between NWPs and cities is constructed based on a multi-level highway system as the basic data, without considering the combination of railway and aviation networks, which to some extent affects the accessibility measurement. Lastly, this research is limited to a case study in China and lacks exploration on other cases elsewhere in the world. A validation study comparing various regions at a global scale may be needed in the future.

5.2. Conclusions

An NWP is a high-level utilization of water resources and a social development product. For a particular water conservation facility to develop into a NWP, it must first ensure its own engineering functions (such as flood control, irrigation, or drought resistance); then, it must have the potential to be an ecotourism destination with cultural, social, or historic heritage values, and it must also improve its management level to be approved by the Ministry of Water Resources. The evaluation of NWPs' spatial distribution and accessibility is crucial for maximizing their economic, social, and environmental benefits, which is compatible with sustainability principles such as comprehensive usage of resources and the resource-utilization-capacity improvement of traditional practices. The following are the general conclusions:

(1) Measuring the distribution of NWPs is an efficient method for determining the spatial pattern of typical water projects with high ecotourism value and the degree of comprehensive utilization of water resources at the national scale. Rich in water resources with enhanced regulations for water management, densely populated, highly urbanized, and with a convenient transportation network, the NWP agglomeration areas share similar regional characteristics. The spatial consistency between NWPs, river morphology, population, cities, and transportation is a consequence of the interaction between natural geographical factors and social-economic geographical factors, and will serve as a guide for sustainable regional planning.

(2) NWPs can function as detectors of various endowment and management modes of basin-scale water resources. As each category of NWPs developed from the corresponding water project, it became crucial to determine which water projects should be prioritized for upgrading to new NWPs and where. The optimal arrangement of the six categories of NWPs can not only optimize the allocation of water management resources, but also promote regional growth. Using existing examples as a guide, WLD-Type NWPs should be located in the middle or lower portions of rivers for optimal wetland utilization. URL-Type NWPs should concentrate around major cities along the regional development axis to coordinate urbanization; NRL-Type NWPs should be located near primary streams to serve as critical protecting nodes for important rivers and to generate sufficient ecological flow; RES-Type NWPs should be located in secondary main streams or tributaries to achieve the multipurpose utilization of medium- or small-sized reservoirs. The distribution patterns of WSC-Type and IRA-Type NWPs are not readily apparent and require additional investigation.

(3) The accessibility of NWPs is an effective indicator of the degree to which scenic water resources and population distribution are spatially matched. The map of accessibility values is spatially auto-correlated and unevenly agglomerated, which can be identified by the ESDA-generated LISA map and quantitatively evaluated by Moran's *I*. According to the characteristics of the map of accessibility, the NWPs should be viewed as a series of systematic source locations that provide both ecological and socioeconomic benefits for the surrounding area. Universal suggestions can be made in order to achieve equity in the allocation of NWP resources and to prevent the overdevelopment of water tourism. In areas where accessibility is high–high, there is little need to create new NWPs; however, the socioeconomic benefits can be enhanced by increasing the popularity and capacity of existing NWPs as tourist destinations to attract out-of-town visitors. Both the content and quantity of NWP must be enhanced

in the low-accessibility regions. In addition, some typical water facilities near urban areas can be transformed into new NWPs to attract local and short-distance visitors. In regions with high–low, low–high, or insignificant accessibility characteristics, the NWP systems should adopt a more diversified development strategy and form alliances with other types of natural scenic areas, aiming for a balance between social, economic, and environmental objectives.

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