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Evaluation and Spatial Equilibrium Analysis of High-Quality Development Level in Mainland China Considering Water Constraints

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Abstract: Water resources are indispensable to human society. High-quality development (HQD) is a multi-faceted, demanding, and sustainable pattern. High-quality development level (HQDL) is an indicator of regional development. Its quantitative calculation is helpful to intuitively understand the current regional development situation, and helps departments make timely adjustments. Spatial equilibrium degree (SED) reflects the development balance among regions. Understanding spatial equilibrium can clarify regional development differences, promote the sharing of successful experiences, and then achieve common progress. Considering the current development and utilization situation of China's water resources, this study established an improved evaluation index system for HQDL, under water resources constraints. Then, we applied the proposed "single index quantification and multiple index synthesis and poly-criteria integration (SMI-P)" method to quantitatively evaluate the HQDL of China's 31 provincial-level administrative regions (PLARs), from 2010 to 2019. Finally, the calculation method of SED was employed to assess the SED of indicators and HQD in Mainland China. Results show that: (1) the HQDL of 31 PLARs showed a steady upward trend from 2010 to 2019. There were decrease tendencies from the coast to inland, and southeast to northwest in terms of spatial distribution, which shows that China's HQD has achieved remarkable results in the past 10 years, and the development of coastal areas is better; (2) The SED of HQD displayed a slow upward trend, and it has remained relatively stable after 2015, indicating that the spatial difference of HQD continued to shrink before 2015 and was relatively stable after that; (3) Water resource constraints played a significant role in well-developed areas, while the economic and social level was still the main constraint in medium and poor level areas. In addition, the spatiotemporal variation of HQDL, SED of HQD and indicators, and constraint effects of water resources on regional HQD, were fully discussed. Our findings not only provide new ideas for future research on HQD, but also possess great significance to China's HQD in the new era.

Keywords: high-quality development level; water constraints; synthetic evaluation; spatial equilibrium degree; Mainland China

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1. Introduction

High-quality development (HQD) is one of the key topics in the world today [1]. "Our Common Future", published by WCED in1987, formally proposed the concept of sustainable development. Since then, humans have begun to re-examine the relationship between themselves and the natural environment. Achieving sustainable development today requires us to solve the problems of high pollution, high consumption, and pollution before treatment [2]. The 2030 Agenda for Sustainable Development, launched in 2016, expanded the SDGs to 17 global development goals involving different aspects and fields [3]. In 2017, China proposed the HQD goal, which has set higher requirements for China's development [4]. Promoting sustainable development is the prerequisite to achieve HQD [5]. Therefore, HQD is not limited to high-quality economics, but also includes aspects of social, resources, and ecological environments. Experts around the world have different interpretations of the connotation of HQD. The difference between "high-quality growth" and "high-speed growth" lies in the quality of growth. "High-quality growth" not only means overall growth, but also indicates the progress in social, political, and religious factors [6]. For instance, Mlachila et al. [7] argued that "high-quality growth" is higher and more durable than socially-friendly growth. Pan et al. [8] divided the connotation of HQD into five dimensions: environmental impact, economic development, innovation efficiency, people's livelihoods, and ecological services. Jiang et al. [1] interpreted HQD from aspects of society including resources, economy, ecology, and culture. Various interpretations of the connotation of HQD make its quantitative evaluation more comprehensive, and determines the evaluation system needs to include different aspects and indicators. However, the current evaluation index system for HQD has not highlighted the constraint of water resources.

Water resources are strategic resources that support the development of the economy and society, and maintain a healthy ecosystem [9]. Its effective use can support HQD [10]. However, according to the 2020 UN "Sustainable Development Goals Progress Report", the global water shortage in Central Asia, South Asia and North Africa was extremely high, exceeding 70%. China is rich in freshwater resources, but its per capita water resources are one quarter of the world's, making it a country with moderate water shortages [4]. China's long-term extensive economic growth, lax ecological supervision, and large differences in resource utilization among regions have led to inefficient use of water, and further inhibited the HQD [11]. The carrying space of water determines the growth space for HQD, and its utilization exists in all aspects of production, life, and ecology. The carrying capacity of water resources, water environment and water ecology in China is limited, which determines that the mode and scale of development must be controlled. Otherwise, it will result in shortage and over-exploitation of water, which will neither achieve sustainable utilization of water, nor support economic and social development, and will also lead to a series of ecological and environmental problems. As water scarcity becomes a global problem, ensuring water availability and sustainable management has been adopted as one of the UN's Sustainable Development Goals (SDGs). Experts have successively carried out research on water resources management, such as water resources optimal allocation, water resources scheduling, water and soil resources conservation, and water environment maintenance and improvement. Wang et al. [12] provided a new approach for integrated water resources management to enhance the sustainability of regional water resources. Hatamkhani et al. [13] established a simulation optimization method based on Water Evaluation and Planning to solve the problem of maximizing power generation and minimizing flood damage in Bakhtiari Dam Hydropower Station. Nava et al. [14] explored the challenges and opportunities in the field of water separation. Based on the economic and social factors of water supply and demand, the establishment of water allocation models reduced social inequalities [15]. The multi-objective optimal allocation model, based on the constraints of "three red lines", provided a reference scheme for the sustainable utilization of water resources [16]. Combining legal and technical approaches to water distribution in transboundary rivers, Avarideh et al. [17] developed a conceptual model to quantify the fair and equitable distribution of water. Various optimal scheduling models for multi-reservoir systems enabled efficient use of water resources, protecting the environment, and reducing hydraulic losses [18,19]. Although there are many breakthrough studies on water resource management, there are currently insufficient studies on the effect and sensitivity analysis of water resources on regional HQD in the new era. Xi Jinping emphasized that water resources should be taken as the biggest constraint. The importance of regional high-quality development level (HQDL) evaluation is unquestionable, and it is of great significance to integrate water resources into the HQDL evaluation system. Evaluation results can better provide improvement directions for water resource management in different regions in the future.

Multiple methods have been widely used in the quantitative evaluation of HQDL, including the comprehensive coordination and cross-efficiency evaluation model, based on the data envelope evaluation model [20], AHP and TOPSIS [21], BP-Neural Network [22], System Dynamics [23], and other methods. The application of these methods has enriched the HQDL evaluation system. Among them, the "single index quantification and multiple index synthesis and poly-criteria integration (SMI-P)" method is widely used in the field of human-water harmony, and is dedicated to quantifying the relationship among systems. It can fully combine the conditions of multiple systems to obtain a reasonable HQDL [1]. Furthermore, "Equilibrium" refers to the quantitative equality of things, and the unity of the system [24]. In recent years, there have been many different interpretations of the concept and connotation of spatial equilibrium. Chen et al. [25] used spatial equilibrium to describe the distribution of regional productivity, and Lu [26] applied it to display the equilibrium between natural resource utilization demand and economic production. Zuo et al. [27] discussed that spatial equilibrium is to follow the adaptation principles of population, resources, environment, and ecology to achieve coordinated development of water resource allocation, and social economy. It can be seen that there is a very close relationship between spatial equilibrium and HQD. To measure HQD in China, the regional differences must be fully considered, thus the spatial equilibrium analysis should be employed. Besides, most of the exploration of HQDL and spatial equilibrium in China is concentrated at the provincial level [28], the Yellow River Basin [29], and other smaller areas. There is still a lack of research on expanding the study area to the whole country, so this study can also provide references for the practical application of HQD theory in large-scale areas.

The innovations of this study are: (1) From the perspective of water resource constraints, combined with China's actual situation, we improved the HQDL index evaluation system and provided a "human-water harmony" perspective; (2) We combined HQD with spatial equilibrium theory to further elucidate the spatial differences of HQD in China; (3) We focused on the constraint effects of water resources on regional HQD, and analyzed examples. The main problems addressed in this study are: (1) Establishing an improved HQDL evaluation system by considering water resource constraints and the status quo of 31 provincial-level administrative regions (PLARs) in China; (2) Quantifying the spatial equilibrium degree (SED) of HQD and indicators by introducing the spatial equilibrium theory and using the SED calculation method; (3) Analyzing the spatial features of HQDL among 31 PLARs and clarifying the main influencing indicators of its spatial differences; (4) Discussing the constraint effects of water resources on regional HQD. The general steps of this research are as follows: (1) Under the full consideration of the feature of China's water resources, four criteria are set and 19 representative indicators are selected to establish the HQDL evaluation index system; (2) The HQDL of 31 PLARs in China, from 2010 to 2019, is quantified with the SMI-P method; (3) The calculation method of SED is employed to assess the SED of HQD in Mainland China; (4) The results of HQDL and its SED in 31 PLARs are fully discussed; we then analyzed the constraint effects of water resources on regional HQD. It is of great theoretical and practical significance to interpret HQD in the new era, and give due attention to the relationship between humans and water, in order to provide new ideas for future research on HQD.

2. Methodology

The HQDL index system set four criteria, including resource utilization, economy society, ecological environment, and human-water relationship. We selected 19 representative indicators. The "single index quantification and multiple index synthesis and poly-criteria integration" (SMI-P) method was used to calculate HQDL, and the calculation method of spatial equilibrium degree (SED) was used to calculate the SED of HQD. Figure 1 shows the research methodology and evaluation ideas of this paper.

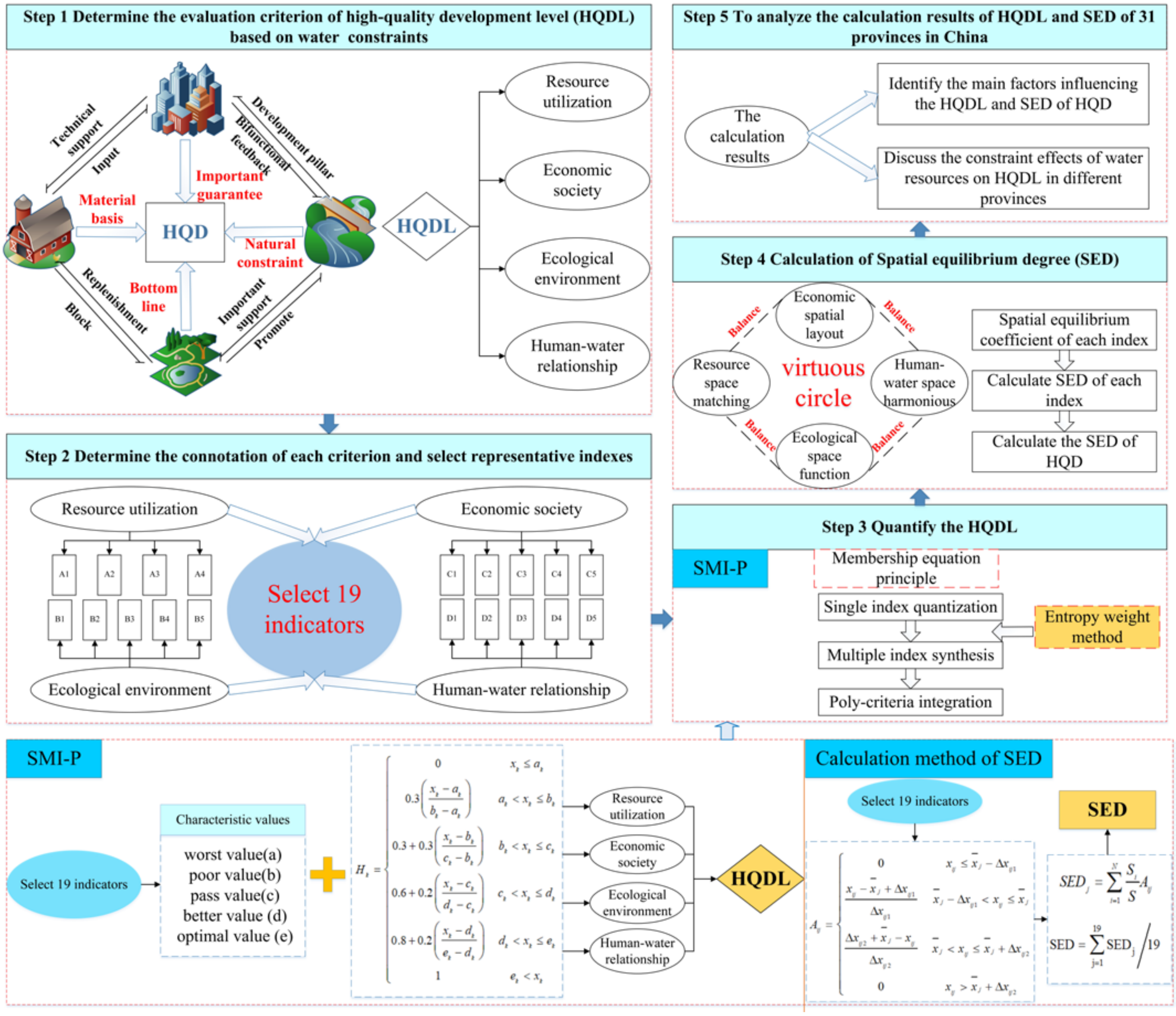


Figure 1. Research methodology and evaluation ideas.

2.1. Evaluation Index System of HQDL

At present, there is no unified index system for the evaluation of HQDL that can meet different research purposes and regions [30]. Among them, most index systems usually include economic [31], ecological [32], environmental [33], and livelihood indicators [34]. However, the above studies do not pay enough attention to resources, and always ignore the constraint of water resources. Besides, the general index system uses more economic indicators than ecological indicators. It makes HQD more affected by the economy, and cannot comprehensively summarize the connotation of HQD. Therefore, this study aims to establish a scientific index system that can highlight the important position of water constraints and comprehensively quantify the HQDL. On this basis, we set up four subsystems: resource utilization, economic society, ecological environment, and human-water relationship. The human-water relationship system is a characteristic system to highlight the role of human-water. It focuses on the relationship and constraints between water resources and human life, which fully considers aspects such as water use, water development and utilization, and reuse of water resources. With the above considerations, the constraints of current water resources on human beings, and the decision-making effect of the latter to deal with the water shortage, can be reflected. In addition, the resource utilization system was set to represent social resource utilization, including energy, material utilization, food production, and resource supply. The economic social system considers the financial situation, social security, the gap in wealth, and urbanization. The ecological environment system is mainly related to ecological safety, including wastewater, waste gas, garbage disposal, green area, and ecological construction investment. According to the principles of representativeness, comprehensiveness, and data availability, comprehensively considering relevant literature and data, and comparing with the SDGs, 19 typical indicators in Table 1 were selected. Moreover, Figure 2 is a schematic diagram of the index system construction, and Table 1 clearly illustrates the evaluation index system of HQDL based on water constraints.

Table 1. Evaluation index system of HQDL considering water constraints (+ and − indicate positive and negative indicators respectively).

Target Layer	Subsystem Layer	Indicator Layer	Serial Number	Indicator Attributes
HQDL	Resource utilization	Energy consumption per 10,000 yuan GDP (tons of standard coal)	A_1	−
		Comprehensive utilization rate of industrial solid waste (%)	A_2	+
		Grain production per unit area (kg/hectare)	A_3	+
		Resource supply penetration rate (%)	A_4	+
	Economic society	Engel coefficient	B_1	−
		Social security and stability index	B_2	+
		GDP per capita (yuan)	B_3	+
		Urbanization rate (%)	B_4	+
		Per capita income ratio of urban and rural residents	B_5	−
	Ecological environment	Total wastewater discharged per 10,000 yuan GDP (ton)	C_1	−
		Carbon dioxide emissions per 10,000 yuan GDP (ton)	C_2	−
		Harmless treatment rate of garbage (%)	C_3	+
		Coverage rate of green space in the completed area (%)	C_4	+
		The proportion of total investment in the treatment of the environment in GDP (%)	C_5	+
	Human-water relationship	per capita water resources (m^3)	D_1	+
		per capita water consumption (m^3)	D_2	+
		Water resource reuse rate (%)	D_3	+
		Water penetration rate (%)	D_4	+
		Utilization ratio of water resources (%)	D_5	−

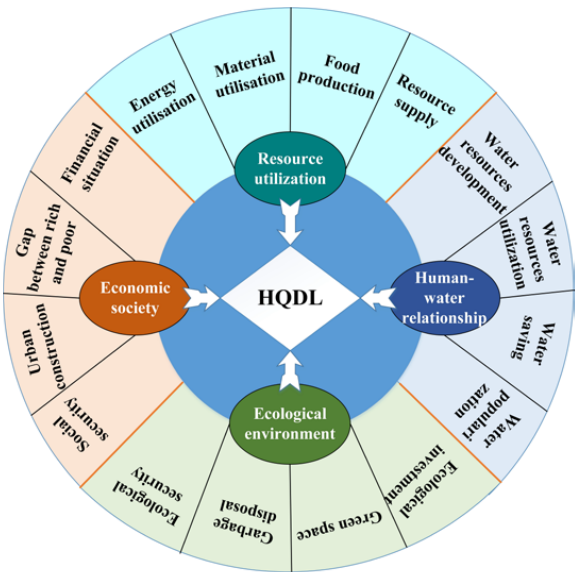


Figure 2. The connotation of index system construction.

2.2. Quantitative Method of HQDL

The SMI-P method has been widely used in the evaluation of harmonious relations among systems, which is a reasonable and comprehensive evaluation method [35,36]. This paper adopts it to evaluate the HQDL; the steps include three aspects. The following is a detailed introduction of the method:

(1) Single index quantization: Calculating the membership degree of each index (denoted as "H", "H ∈ [0, 1]"). Indicators can be quantified by piecewise linear membership function, and mapped to the range of "[0, 1]". The calculation formulas for membership degree of positive and negative indicators are as follows:

$$H_k = \begin{cases} 0 & x_k \le a_k \\ 0.3\left(\frac{x_k-a_k}{b_k-a_k}\right) & a_k < x_k \le b_k \\ 0.3+0.3\left(\frac{x_k-b_k}{c_k-b_k}\right) & b_k < x_k \le c_k \\ 0.6+0.2\left(\frac{x_k-c_k}{d_k-c_k}\right) & c_k < x_k \le d_k \\ 0.8+0.2\left(\frac{x_k-d_k}{e_k-d_k}\right) & d_k < x_k \le e_k \\ 1 & e_k < x_k \end{cases} \quad H_k = \begin{cases} 1 & x_k \le e_k \\ 0.8+0.2\left(\frac{d_k-x_k}{d_k-e_k}\right) & e_k < x_k \le d_k \\ 0.6+0.2\left(\frac{c_k-x_k}{c_k-d_k}\right) & d_k < x_k \le c_k \\ 0.3+0.3\left(\frac{b_k-x_k}{b_k-c_k}\right) & c_k < x_k \le b_k \\ 0.3\left(\frac{a_k-x_k}{a_k-b_k}\right) & b_k < x_k \le a_k \\ 0 & a_k < x_k \end{cases} \quad (1)$$

where H_k is the membership degree of the kth index; $x_k, a_k, b_k, c_k, d_k, e_k$, respectively represent the actual value, worst value, poor value, pass value, better value, and optimal value of the kth index. The node values were selected according to various plans and standards in China, and the methods in setting $a_k = \min(x_k)$, $e_k = \max(x_k)$, $c_k = \overline{x}_k$, $b_k = \frac{(a_k+c_k)}{2}$, $d_k = \frac{(c_k+e_k)}{2}$ were used to determine if there is no standard [1]. The node values selected for each indicator are shown in Table 2.

(2) Multiple index synthesis: by weighting the membership degree of multiple indices, the HQDD of each criterion layer can be calculated. The formula is as follow:

$$HQDD_t = \sum_{k=1}^{n} w_k H_k \quad (2)$$

where $HQDD_t$ is the high-quality development degree of the t criterion layer; w_k is the weight that determined by entropy weight method, and $\sum\limits_{k=1}^{n} w_k = 1$. Entropy weight method is commonly used to determine the weight [37]. The basic idea of the entropy weight method is to determine the objective weight according to the index variability. Generally speaking, the smaller the information entropy of the index is, the greater the degree of variation is, and the greater the role it can play in comprehensive evaluation.

(3) Poly-criteria integration: the HQDD of each criterion layer can be obtained through the above calculation, then the HQDL is calculated by the weighted average method:

$$HQDL = \sum_{t=1}^{m} \omega_t HQDD_t \quad (3)$$

where ω_t is the weight of the t criterion layer. We believe that the four subsystems are equally important for quantitative evaluation of HQDL [38], so $\omega_1 = \omega_2 = \omega_3 = \omega_4 = 0.25$. Furthermore, the classification of HQDL refers to the threshold level, as shown in Table 3.

Table 2. The characteristic values of evaluation index.

Evaluation Index	The Characteristic Value				
	a	b	c	d	e
A_1	3.6	2.2	0.8	0.5	0.2
A_2	1.6	41.0	80.3	95.0	109.8
A_3	2741.2	4258.4	5775.7	7381.3	8987.0
A_4	47.3	72.4	97.5	103.7	100.0
B_1	12,185.8	6310.5	435.1	290.1	145.1
B_2	11,593.8	35,753.0	59,912.2	120,465.8	181,019.3
B_3	0.1	0.4	0.7	0.9	1.0
B_4	20.4	41.9	63.5	81.0	98.6
B_5	4.5	3.5	2.4	2.1	1.7
C_1	40.2	25.3	10.4	7.1	3.7
C_2	4.4	2.3	0.2	0.1	0.0
C_3	0.2	0.4	0.7	3.3	6.0
C_4	16.3	28.3	40.4	47.2	54.0
C_5	34.2	62.6	91.0	100.5	100.0
D_1	46.7	666.8	1287.0	85,168.5	169,050.1
D_2	2.4	37.5	72.7	89.1	105.6
D_3	12,185.8	6310.5	435.1	290.1	145.1
D_4	920.0	504.0	88.0	44.3	0.6
D_5	60.8	79.6	98.5	104.2	100.0

Table 3. The grading standard of HQDL.

Lever	No Lever	Very Poor	Poor	Medium	Good	Excellent	Ideal
HQDL	0	(0, 0.2)	[0.2, 0.4)	[0.4, 0.6)	[0.6, 0.8)	[0.8, 1)	1

2.3. Calculation Method of SED

"Equilibrium" refers to the quantitative equality of things and the unity of the system. "Spatial equilibrium" is a relatively stable equilibrium state in space [39]. The spatial equilibrium idea has been applied in many fields, involving land use, industrial economy, tourism and shipping, and medical and health, as well as the spatial management of water resources [24]. SED is an important indicator to measure the degree of spatial equilibrium. The larger the value, the smaller the difference between regions. Specifically, Zuo et al. [39] proposed the spatial equilibrium theory and quantitative method, which can be expressed as follows:

(1) Calculate the spatial equilibrium coefficient A_{ij} of index j of region i:

$$A_{ij} = \begin{cases} 0 & x_{ij} \le \overline{x}_j - \Delta x_{ij1} \\ \frac{x_{ij} - \overline{x}_j + \Delta x_{ij1}}{\Delta x_{ij1}} & \overline{x}_j - \Delta x_{ij1} < x_{ij} \le \overline{x}_j \\ \frac{\Delta x_{ij2} + \overline{x}_j - x_{ij}}{\Delta x_{ij2}} & \overline{x}_j < x_{ij} \le \overline{x}_j + \Delta x_{ij2} \\ 0 & x_{ij} > \overline{x}_j + \Delta x_{ij2} \end{cases} \tag{4}$$

where x_{ij} is the original data of index j of region i; $\overline{x}_j$ is the average value of index j; Δx_{ij1} and Δx_{ij2} are the values of $\overline{x}_j$ in each region increasing or decreasing in the positive or negative direction when the spatial equilibrium coefficient is 0. Since the values of all indicators are at [0, 1], it is assumed $\Delta x_{ij1} = \overline{x}_j$, $\Delta x_{ij2} = 1 - \overline{x}_j$.

(2) Calculate the of SED_j indicators:

$$SED_j = \sum_{i=1}^{N} \frac{S_i}{S} A_{ij} \tag{5}$$

where S_i is the area of region i; S is the total area of the study area.

(3) Calculate the SED of HQD:

The contribution of each indicator can be characterized by weights. In this paper, it is assumed that the weights of all indicators are equal, then the *SED* of HQD is:

$$SED = \sum_{j=1}^{19} SED_j / 19 \tag{6}$$

The larger the *SED*, the higher the degree of spatial equilibrium and the smaller the regional differences.

3. Case Study

3.1. Overview of the Study Area

China is rich in water resources, but per capita water resources in 2019 were only 2062.9 m^3, which is one quarter of the global average, and belongs to the list of water-scarce countries. According to latest statistics released by the World Bank in 2018, China's per capita renewable inland freshwater resources were 2005 m^3, nearly one third of the global level, while Japan, which is geographically similar to China, had 3391 m^3. The United States reached 8662 m^3, four times that of China.

China's water consumption has continued to increase since 2000, reaching 6.02×10^{11} m^3 in 2019, an increase of 5.7×10^9 m^3 from 2018. Agriculture used the most water, 3.68×10^{11} m^3, which is 61.2%. Domestic and industrial use accounted for 14.5% and 20.2%, respectively. The artificial ecological environment used 2.5×10^{10} m^3 of water, accounting for 4.15% of the total water supply. Moreover, total wastewater discharge reached 7.35×10^{10} *t* in 2015, a 77% increase from 2000 [40]. Increased water demand and pollution contribute to China's water scarcity; water shortage then restricts the process of HQD. In addition, the spatial and temporal distribution of water resources in China is uneven, with abundant water resources in coastal cities, and more severe water shortage in Western China. Different regional water balance levels have different impacts on HQDL. Therefore, this paper selects 31 PLARs in China as the study area to explore their HQDL, and its spatial equilibrium situation under the constraint of water resources. Figure 3 is the location and general situation of research area in this paper.

Figure 3. Map of the study area.

3.2. Data Sources

The data of the indicators come from the National Bureau of Statistics and the Ministry of Water Resources, including *The China Statistical Yearbook*, *The China Science and Technology Statistical Yearbook*, *The China Environmental Statistical Yearbook*, *The China Urban and Rural Construction Statistical Yearbook*, and *The China Energy Statistics Yearbook*, as well as *The Provincial Statistical Yearbooks* and *Water Resources Bulletins*.

4. Results

4.1. Evolution of Subsystems' HQDD

4.1.1. Evolution of Resource Utilization Subsystem's HQDD

Figure 4 shows the HQDD spatial distribution of the resource utilization system in 2010, 2013, 2016, and 2019. It can be seen that there is a great difference in the HQDD among PLARs. Although the overall development state is improving, PLARs at a poor level have developed slowly for many years, and the provincial differences are becoming increasingly obvious over the years. For instance, the HQDD of coastal cities were at a good level in 2010, the central and eastern regions were at a medium level, and the western regions, except for Xinjiang, were at a poor level, showing an obvious cluster situation from east to west. Among them, Qinghai and Shanghai have a huge gap, whose HQDD are 0.276 and 0.725, respectively. In 2013, only Qinghai (0.324), Tibet (0.373), and Guizhou (0.351) remained at a poor level, while the northern provinces of China developed rapidly. In 2016, Shanghai (0.800) entered a good level of resource utilization, while only Qinghai (0.352) was at a poor level. In 2019, Beijing (0.802) and Jiangsu (0.817) entered an excellent level, while Hubei (0.644) was added to a good level, but Tibet (0.377) re-entered a poor level. In the study period, the HQDD of Ningxia and Sichuan had the fastest development, with an increase of 0.228 and 0.213, respectively.

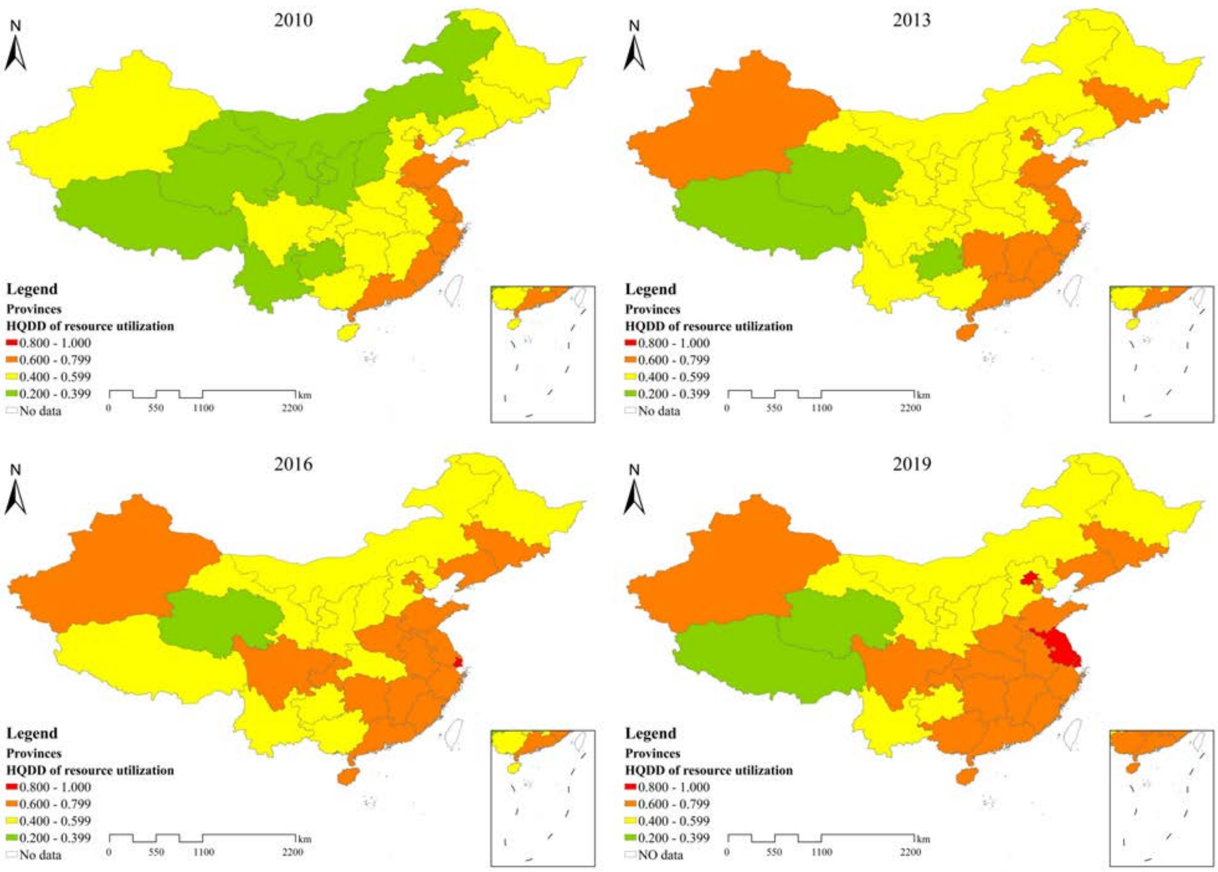


Figure 4. Spatial distribution of HQDD of the resource utilization system in 31 PLARs in 2010, 2013, 2016, and 2019.

4.1.2. Evolution of Economic Society Subsystem's HQDD

Figure 5 presents the HQDD of the economic society system of the study areas. It can be seen that the economic social development process of China's PLARs is relatively fast, and there is a rapid development trend from east to west, with Beijing as the center. In 2010, only Beijing (0.737), Tianjin (0.681), and Shanghai (0.684) entered a good level, and most PLARs were at a medium level, while most of the western PLARs were still at a poor level. In 2013, Guangxi (0.417), Guizhou (0.423), and Yunnan (0.430) entered a medium level, while Shandong (0.627) and Jiangsu (0.613) turned into a good level. In 2016, Hebei (0.617), Henan (0.646), and Chongqing (0.630) all reached a good level, and the central regions developed rapidly. The level of economic social development in the western PLARs is also improving. From 2016 to 2019, the economy of all PLARs developed rapidly, and in 2019, all PLARs came up to a medium level or above stage, among which 20 PLARs were at a good level. Among them, Tianjin and Beijing had the highest HQDD, while Xinjiang and Gansu had the worst scores; the difference between Tianjin and Xinjiang was 0.326. From the overall trend of HQDD, the current development of economic society is still very fast.

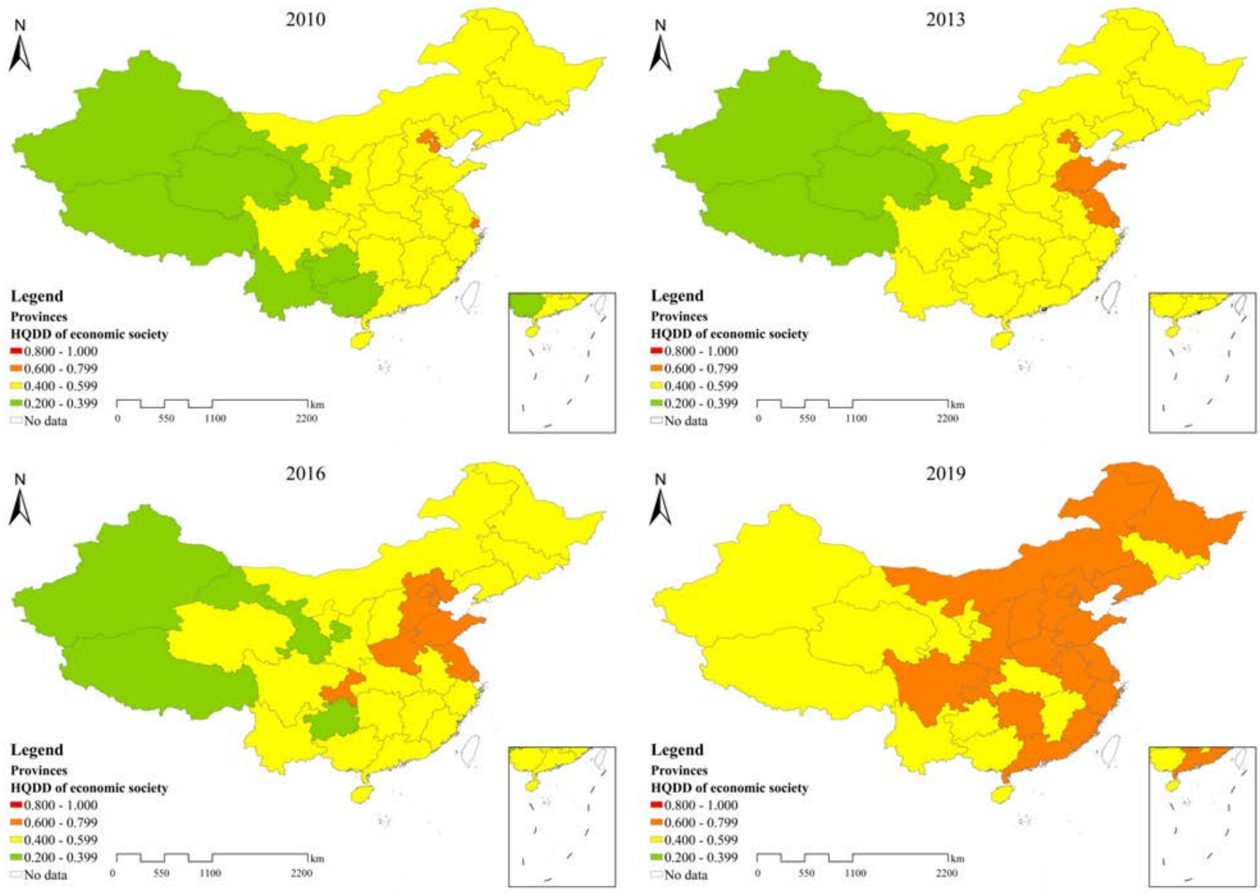


Figure 5. Spatial distribution of HQDD of the economic society system in 31 PLARs in 2010, 2013, 2016, and 2019.

4.1.3. Evolution of Ecological Environment Subsystem's HQDD

Figure 6 displays the HQDD of the ecological environment system in 2010, 2013, 2016, and 2019. The ecological environment in most parts of China has improved significantly in the past decade. In 2010, only Beijing (0.655) and Chongqing (0.611) reached a good level. In 2013, some PLARs in central and eastern China continued to improve their ecological environment quality, and the number of PLARs that reached a good level increased to seven, with scattered spatial distribution. In 2016, the ecological environment of all PLARs entered the stage of rapid improvement. Only some PLARs in the Northwest and Northeast China were still at a medium level, while other regions turned into a good level. Among them, Beijing has entered an excellent level, and the HQDD has reached 0.825. In contrast, Gansu (0.545), Qinghai (0.597), and Xinjiang (0.578) in Northwest China, and Liaoning (0.519), Jilin (0.586), and Heilongjiang (0.555) in Northeast China, have lower scores. In 2019, all PLARs in the study area were at a good level or above, with Beijing scoring the highest (0.842) and Liaoning scoring the worst (0.600).

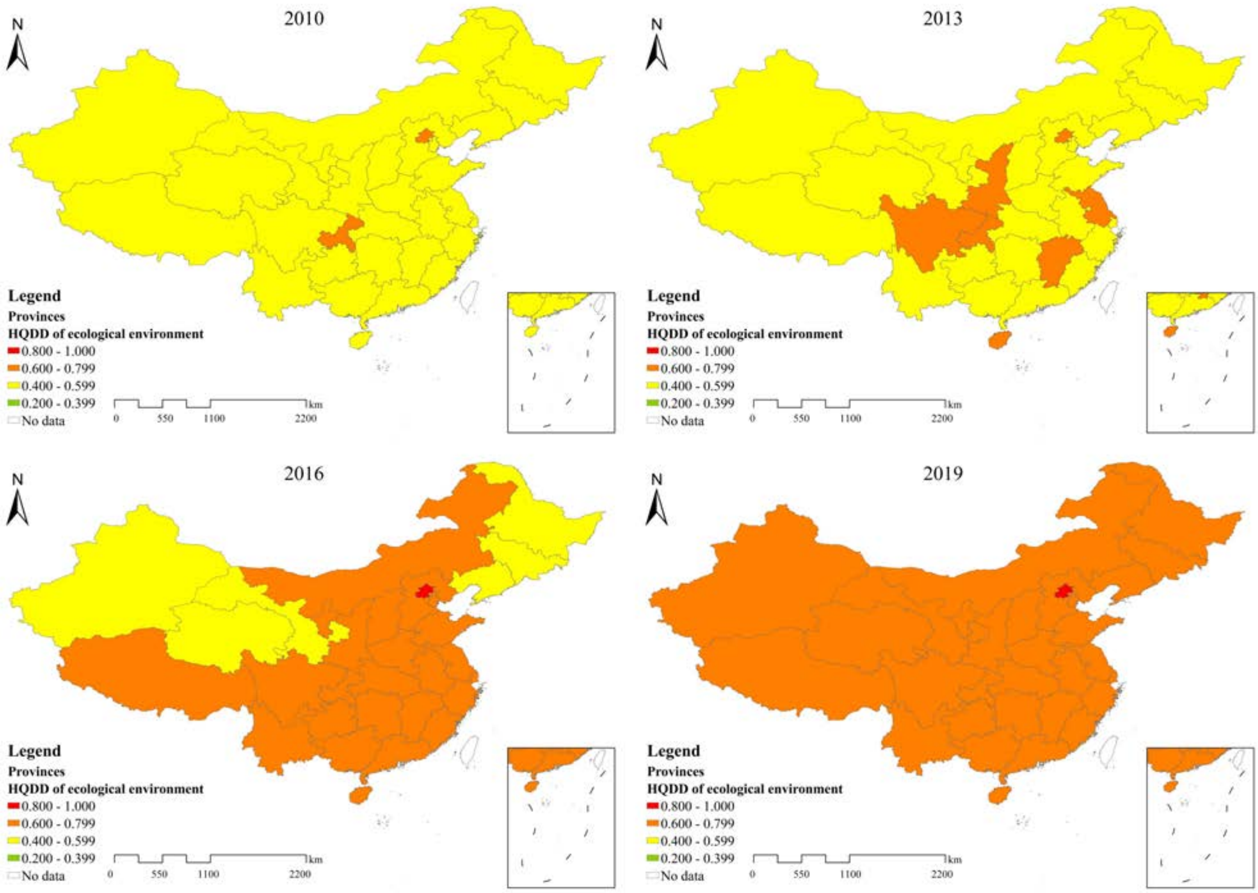


Figure 6. Spatial distribution of HQDD of the ecological environment system in 31 PLARs in 2010, 2013, 2016, and 2019.

4.1.4. Evolution of Human-Water Relationship Subsystem's HQDD

Figure 7 illustrates the HQDD of the human-water relationship system in each province, based on the results of 2010, 2013, 2016, and 2019. The HQDD in most PLARs of China is at a medium or good level; the evolution of each province is different and unique. In 2010, a total of 20 PLARs entered a good level, with Liaoning achieving the highest score among the PLARs at 0.750. Ningxia entered a poor level of HQDD with a score of 0.371, and all other PLARs scored above 0.400. In 2013, Shanghai also briefly entered a poor level (0.386), and the HQDD in Shandong, Henan, and Yunnan declined, with scores of 0.599, 0.574, and 0.578. Heilongjiang (0.628), Chongqing (0.626), and Gansu (0.674) were from a medium level to a good level. In 2016, the HQDD in Gansu experienced twists and turns, then entered a medium level. In 2019, all 31 PLARs in China entered a medium level and above, and most areas had reached a good level. Compared with 2016, Hunan (0.625) reached a good level, and Ningxia (0.436) entered a medium level. Although Henan (0.578) and Hebei (0.567) had twists and turns, they entered a medium level and were close to the good level range. In addition, the HQDD in Beijing, Tianjin, and other PLARs, has remained at a medium level for many years, and Beijing's HQDD in 2019 ranked the lowest among all PLARs, with a score of only 0.435.

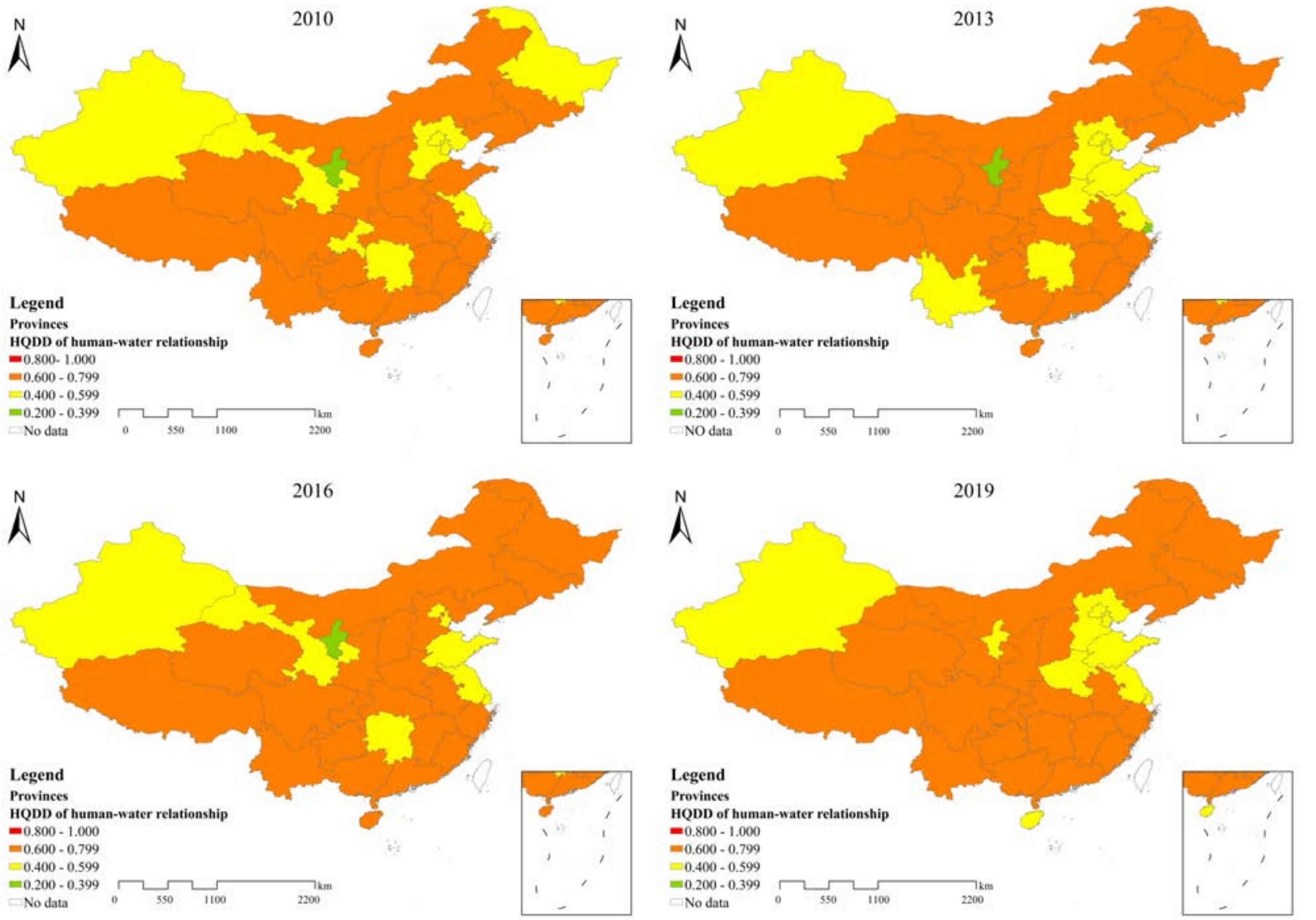


Figure 7. Spatial distribution of HQDD of the human-water relationship system in 31 PLARs in 2010, 2013, 2016, and 2019.

4.2. Evolution of HQDL in China

The results of HQDL of 31 PLARs in China, based on water constraints, are shown in Figure 8, in which the periods of 2010, 2013, 2016, and 2019 are selected to illustrate spatial features. It can be seen from Figure 8 that the development of HQDL showed an obvious spatial trend of gradually decreasing from southeast to northwest. In 2010, only the HQDL in Tianjin (0.604) and Zhejiang (0.606) reached a good level, while the rest of the PLARs all reached a medium level, indicating that the starting point of HQD in each province was relatively high. In 2013, the HQDL of southeast coastal areas was higher, both reaching 0.600 and above; meanwhile, Sichuan (0.611) and Chongqing (0.616) also reached a good level. Under the goal of Rising Strategy of Central China, the central region gradually developed, and 20 PLARs had reached a good level in 2016. Among the 31 PLARs, Zhejiang scored the highest result of 0.734. Beijing's HQDL was greatly affected by the human-water relationship system, with a final score of 0.711 in 2019, and Guangdong's HQDL reached 0.712, ranking second. In the western regions and the central PLARs of Shanxi and Guizhou, the HQDL was below 0.6; Ningxia got the lowest HQDL score (0.514).

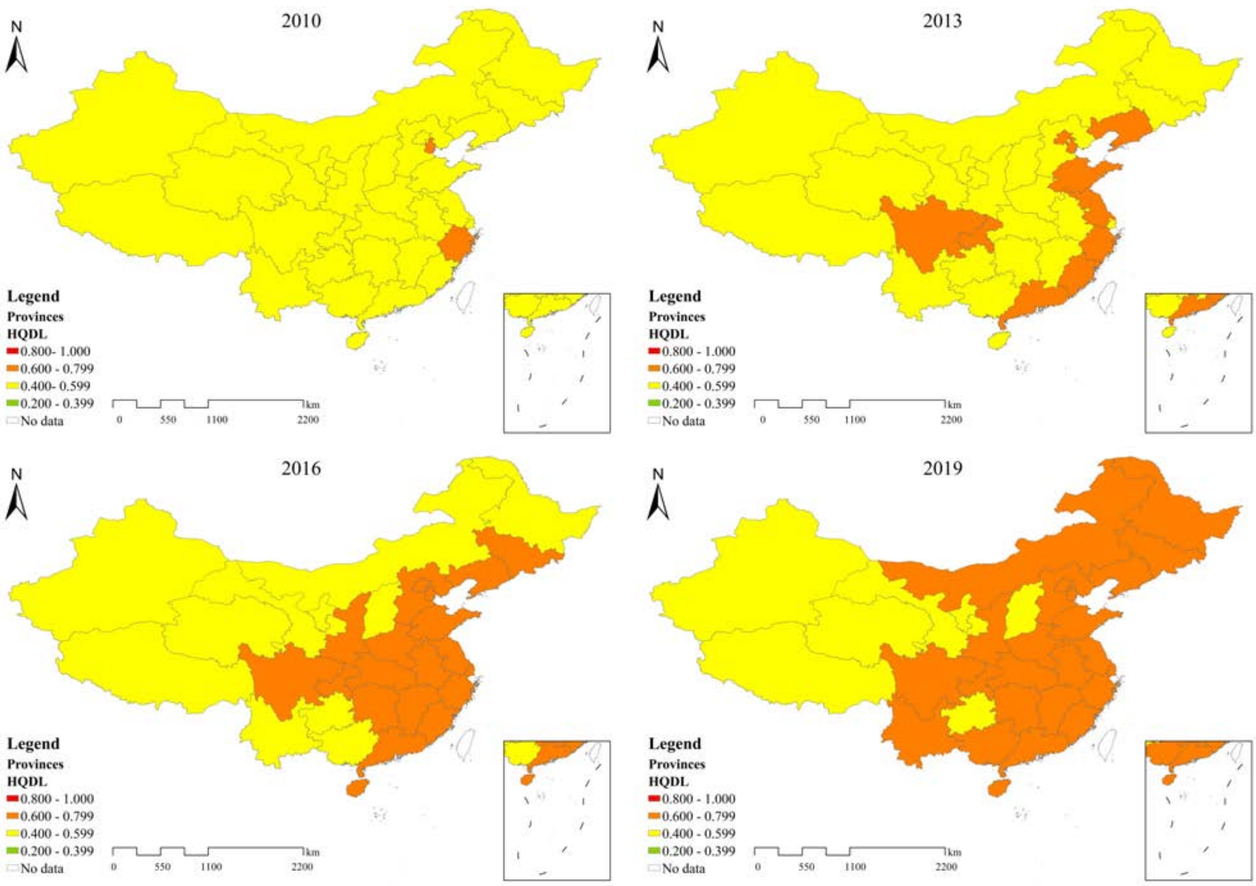


Figure 8. Spatial distribution of HQDL of 31 PLARs in 2010, 2013, 2016, and 2019.

4.3. Evolution of SED

4.3.1. Evolution of SED of Each Indicator

Table 4 shows the SED of various indicators from 2010 to 2019. In total, most indicators have a certain increase during the entire study period. Specifically, all the indicators of the resource utilization system were in an upward trend. The SED of energy consumption per 10,000-yuan GDP was relatively low, with a score of 0.579 in 2019. The SED of the comprehensive utilization rate of industrial solid waste had improved significantly from 2010 to 2016, experiencing twists and turns in 2017, and increased slowly in the following two years, but still did not reach the level of 2012–2016.

In the economic society system, the SEDs of Engel coefficient, and social security and stability indices, have been in a stable state for many years. The SED of Engel coefficient was poor and still does not reach 0.500. The spatial imbalance of GDP per capita, and urbanization rate, has been significantly improved, rising by 0.301 and 0.110, respectively. The SED of per capita income ratio of urban and rural residents was at an extremely low level, with a score of 0.049 in 2019.

The SED of all indices in the ecological environment system were relatively high. The SED of harmless treatment rate of garbage, and coverage rate of green space in the completed area, have been rising steadily for years, reaching 0.916 and 0.948, respectively, in 2019. The index of carbon dioxide emissions per 1000-yuan GDP decreased from 0.573 to 0.488 in terms of its SED. The SED of total wastewater discharged per 10,000-yuan GDP increased continuously from 2010 to 2015, reaching the highest value in 2015 (0.848), and then began to decline.

The changes of SED of indices in the human-water relationship system were relatively gentle. Among them, the SED of water penetration rate in all regions was higher than 0.900 throughout the decade. Per capita water resources, and utilization ratio of water resources, have the lowest scores in this system, which were about 0.300 and 0.400 in past years, respectively. The SED of per capita water consumption changed slightly over the years, and still did not reach 0.500. The SED of water resource reuse rate increased gradually from 2010 to 2019, reaching 0.592 in 2019.

Table 4. The SED of all indicators from 2010 to 2019.

Indicators	SED									
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
A_1	0.403	0.505	0.541	0.538	0.556	0.576	0.596	0.589	0.577	0.579
A_2	0.643	0.684	0.732	0.758	0.721	0.779	0.772	0.705	0.716	0.725
A_3	0.823	0.820	0.827	0.824	0.834	0.822	0.863	0.853	0.861	0.854
A_4	0.942	0.946	0.901	0.931	0.945	0.958	0.926	0.946	0.943	0.949
B_1	0.479	0.479	0.494	0.491	0.486	0.492	0.489	0.490	0.487	0.494
B_2	0.763	0.750	0.751	0.700	0.680	0.685	0.685	0.718	0.713	0.721
B_3	0.495	0.579	0.636	0.693	0.736	0.742	0.759	0.799	0.807	0.796
B_4	0.753	0.775	0.785	0.795	0.812	0.826	0.840	0.851	0.859	0.863
B_5	0.058	0.056	0.055	0.052	0.051	0.051	0.051	0.051	0.050	0.049
C_1	0.631	0.733	0.759	0.817	0.844	0.848	0.816	0.764	0.713	0.666
C_2	0.573	0.568	0.534	0.521	0.519	0.511	0.489	0.477	0.468	0.488
C_3	0.824	0.871	0.884	0.889	0.916	0.925	0.926	0.930	0.929	0.916
C_4	0.862	0.873	0.909	0.861	0.923	0.929	0.924	0.934	0.945	0.948
C_5	0.537	0.521	0.556	0.581	0.561	0.528	0.549	0.505	0.553	0.561
D_1	0.334	0.263	0.309	0.365	0.276	0.332	0.352	0.288	0.280	0.290
D_2	0.479	0.479	0.494	0.491	0.486	0.492	0.489	0.490	0.487	0.494
D_3	0.581	0.543	0.555	0.557	0.573	0.588	0.578	0.595	0.591	0.592
D_4	0.964	0.964	0.948	0.984	0.974	0.974	0.945	0.980	0.973	0.983
D_5	0.352	0.429	0.402	0.346	0.396	0.405	0.395	0.405	0.393	0.363

4.3.2. Analysis of the Relative Level of Economic-Social Development

The SED of HQD of 31 PLARs are exhibited in Figure 9. It can be seen from Figure 9 that SED presents a slow upward trend on the whole, but there is little change over the years, which is above 0.600. Among them, the highest value was 0.656 in 2015. After 2015, the SED of HQD was around 0.650, which remained in a relatively stable state, indicating that HQD in each province had entered a stage of long-term stable development.

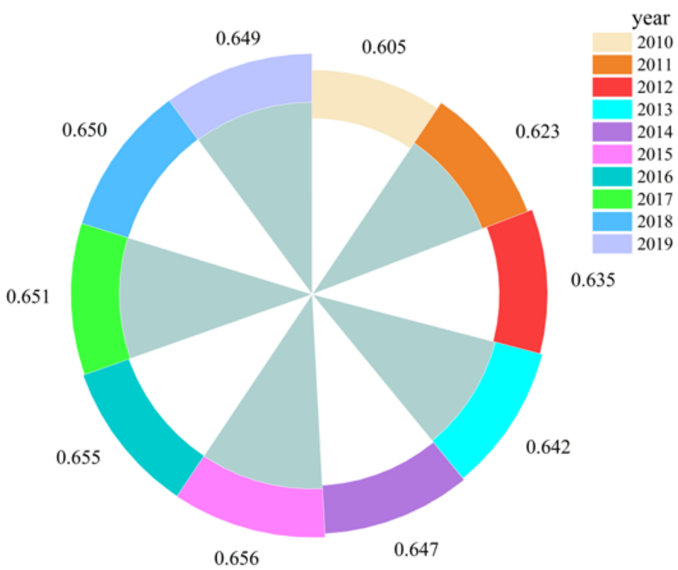


Figure 9. The SED of HQD from 2010 to 2019.

5. Discussion

5.1. Spatiotemporal Variation of HQDL

The HQDL of 31 PLARs shows a trend of increasing during the study period, in terms of time, but decreasing from southeast to northwest, in terms of space. The continuous improvement of HQDL shows that the development model of Mainland China is generally effective, and certain results have been achieved. After the reform and opening up, coastal cities had rapid economic and social development, rich water resources, good ecology, and outstanding science and technology level, which resulted in efficient resource utilization. Good performance in the above aspects put their HQDL in the leading position in China [41]. The main reasons for poor HQDL in the western region were inconvenient transportation, slow economic development, and poor social stability. In addition, the low annual and inter-annual precipitation, the excessive development of water resources, and continuous soil erosion also lead to the lack of development in the west [42].

From the provincial perspective, the HQDL of Zhejiang, Guangdong, and Beijing ranked the highest in Mainland China in 2019, and they were all located in the center of economic development. Zhejiang and Guangdong had relatively rich water resources and a good relationship between humans and water. Beijing is the capital of China and the economic center of the north, so its economic social developmental level, ecological environment condition, and resource supply are at a good level. However, with urban development and modernization, the water shortage situation in Beijing is increasingly severe because of the high population density, and the large increase in urban water consumption [41]. It relies on water resources supplied by the South-to-North Water Diversion Projects [43], and its water shortage has become a long-standing problem, leading to Beijing's HQDL ranking third. Zhejiang received the highest score among the study area, which is owing to the balanced development of all aspects, with a score of 0.686 for ecological environment system, and higher than 0.7 for other subsystems. Guangdong also performed well in all systems, with an HQDL score of 0.712 in 2019, ranking second.

The HQDL of most central PLARs had reached a good level, while that of Shanxi and Guizhou provinces was below 0.6, lagging behind the neighboring PLARs. The membership degrees of Shanxi's energy consumption per 10,000-yuan GDP, grain production per unit area, and the comprehensive utilization rate of industrial solid waste were all less than 0.6; meanwhile, that of the comprehensive utilization rate of industrial solid waste was still declining, with a score of only 0.290 in 2019. As a resource-rich province, it is necessary for Shanxi to focus on ways to improve the efficiency of resource utilization [44]. Guizhou's economic society and resource utilization subsystems are the main aspects affecting its HQDL. Compared with other PLARs, Guizhou's economic development level is relatively low, and the score of each indicator in the resource utilization system does not reach 0.6, indicating it should consider improving its economic development level and optimize its resource utilization structure. Ningxia, Qinghai, Xinjiang, and Tibet had the lowest HQDL in China, which is mainly related to the inferior geographical position and backward scientific and technological level of the western region.

5.2. Discussion on SED of HQD and Indicators

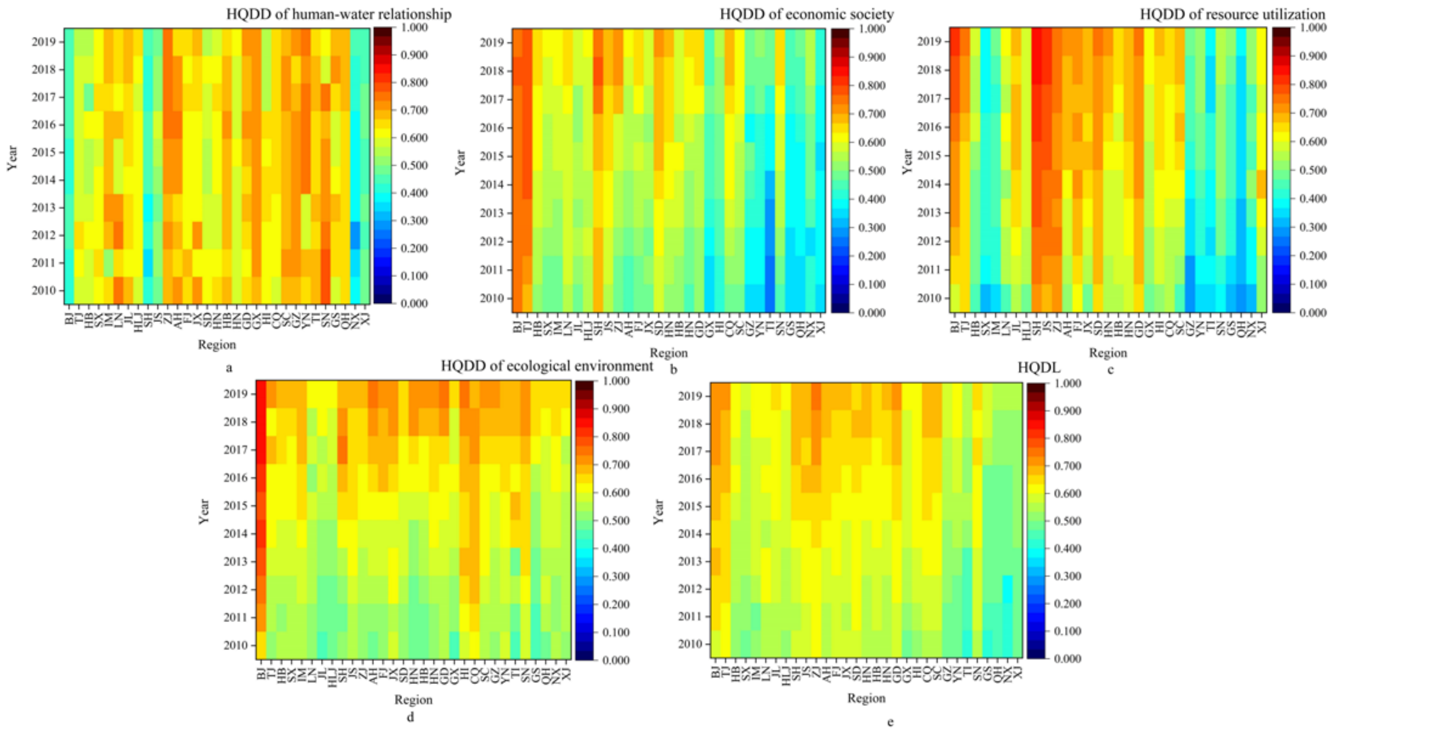
The SED of HQD in Mainland China shows a trend of first increasing and then slightly decreasing inter-annual. From 2010 to 2015, the SED grew rapidly and reached the highest value in 2015. After that, it was in a downward trend as a whole, but the decline rate was very small. The findings prove that the spatial disequilibrium of HQD in China has improved. From a numerical point of view, although there are gaps in the HQD between regions, the spatial balance is good with all of the SED across the years remaining above 0.600. On an inter-annual basis, the economies of various regions entered a stage of rapid development from 2010 to 2015. Western Development and Central Rise plans have enabled the backward regions to obtain more resources and talent supply [45], so the gap among regions has narrowed. Since 2015, remarkable results have been achieved in China's development; the SED has also entered a relatively stable trend. From the perspective of subsystems, the decline in SED of HQD is mainly due to the side effects brought about by rapid economic development. For example, Beijing, Shanghai, Guangzhou, and other developed regions have a large number of foreign population input, and different living habits and communication methods can easily result in social conflicts [46]. The widening gap in the social security and stability index among regions will have a bad impact on the spatial balance. The uneven level of science and technology, and the differences in the discharge and treatment of wastewater and waste gas among regions, will also widen the spatial difference in China's HQD. In addition, the uneven spatial and temporal distribution of water resources also exacerbates the phenomenon of spatial disequilibrium among regions.

From the index level, all indicators' SED of the resource utilization subsystem is in an upward trend. The SED of energy consumption per 10,000-yuan of GDP is relatively low, indicating that there is a certain gap in the level of industrial development among PLARs. However, with the advancement and popularization of science and technology, the gap among PLARs has gradually narrowed, so the SED of this indicator has increased significantly over the years. The downward trend in the comprehensive utilization rate of industrial solid waste is because Shanxi, Inner Mongolia, and other PLARs have dropped significantly in recent years, while most PLARs are still significantly improving their resource recycling capabilities [47]. The steady improvement of the SED of GDP per capita, and urbanization rate in the economic social systems, indicates that China's poor areas have effectively developed. The SED of per capita income ratio of urban and rural residents is at a very low level, revealing that there are large differences in the income of urban and rural residents among PLARs, and no effective improvement has appeared for many years [48]. In the ecological environment system, the SED of harmless treatment rate of garbage, and coverage rate of green space in the completed area, has been rising steadily year by year. It can be attributed to the fact that China has promoted garbage classification in major cities and achieved remarkable results [49]. With people's attention on the ecological service function of green space, the coverage of green space in completed areas has also been improved. The poor SED exists in the index of carbon dioxide emissions per 10,000-yuan of GDP, and the expanding spatial difference demonstrates that regions have various supervision of carbon dioxide emission. It is still an ecological problem that needs to be paid more attention to in some regions, and needs to be improved urgently. China's goal of "carbon emission" and "carbon neutrality" requires regional governments to consider improving the current situation of gas pollution [50]. The SED of total wastewater discharged per 10,000-yuan GDP began to decline from 2015, showing that the gap in wastewater discharge among PLARs had narrowed and then expanded, which had an important relationship with technological development. Regions with advanced technology continue to optimize industrial wastewater discharge, while backward regions have weak technologies, resulting in widening gaps between regions. The score of per capita water resources is the lowest in the human-water relationship system, because of the uneven distribution of water resources in the study area, and then leads to large regional differences. Hence, attention should be paid to the construction of river and lake water system connectivity and multi-regional water transfer projects. The SED of the water resource reuse rate gradually increased from 2010 to 2019, which shows the public's idea of water conservation has been generally improved.

Through calculation and analysis of SED of HQD and Indicators, it can be seen that there are great spatial differences in the HQDL of 31 PLARs. In the area of large spatial differences, we should pay attention to the sharing of resources between regions and draw on successful experience. In the aspect of environment, the optimization design of water conservancy projects, for the purpose of improving the environment, needs to be paid attention to [51,52]. Sewage treatment technology should be promoted, and a large number of emissions of carbon dioxide and other waste gases need to be addressed. In the utilization of resources, we should develop scientific and technological innovation and advocate the secondary use of resources. In the economic aspect, the provision to poor families should be increased to ensure that the social gap between the rich and the poor should be effectively reduced. In terms of human-water relations, the most stringent water management system should be observed to improve water efficiency.

5.3. Constraint Effects of Water Resources on Regional HQD

By comparing the results in Figure 10, it can be seen that the water constraints on HQD are mainly highlighted in well-developed areas. The constraints of water resources on these areas exist in many aspects. Due to the high population density in Beijing, Tianjin, Shanghai, and other regions [53], the situation that the per capita water resources are lower than the national level, always occurred. Moreover, with the acceleration of urbanization, the water consumption for production and domestic use has increased significantly. While the domestic and production water supply needs to rely on large-scale water conservancy projects, such a situation will seriously inhibit the further development of the economy [41]. In addition, ensuring the health and stability of the ecology also requires the supply of a large amount of water resources. Water scarcity in all aspects will seriously affect the long-term and sustainable development of these regions. Therefore, although economic social development, the ecological environment condition, and the resource utilization level of these regions are all at the forefront of the country, the shortage of water resources has hindered the HQD, so the HQDL of these regions is lower than expected. It can be seen that water resources are the main constraints to the development of better areas.



BJ-Beijing	TJ-Tianjin	HE-Hebei	LN-Liaoning	SH-Shanghai	JS-Jiangsu
ZJ-Zhejiang	FJ-Fujian	SD-Shandong	GD-Guangdong	GX-Guangxi	HI-Hainan
SX-Shanxi	IM-Inner Mongolia	JL-Jilin	HL-Heilongjiang	AH-Anhui	JX-Jiangxi
HA-Henan	HB-Hubei	HN-Hunan	CQ-Chongqing	SC-Sichuan	GZ-Guizhou
YN-Yunnan	TI-Tibet	SN-Shaanxi	GS-Gansu	QH-Qinghai	NX-Ningxia
XJ-Xinjiang					

Figure 10. Comparison of HQDD of four subsystem and HQDL from 2010 to 2019 (**a**–**d**) are HQDD of the human-water relationship subsystem, economic social subsystem, resource utilization subsystem and ecological environment subsystem, and (**e**) is HQDL.

For PLARs with medium development level, the constraint effects of water resources on HQD are less than that of economic social constraints. This is because the economic level of these regions is still the main problem faced by the region, and the low economic level restricts the development of the region. For areas with insufficient development, although the constrain effect of water resources is not obvious, the importance of water resources for high-quality development can be clearly seen. In areas with higher HQDD of the human-water relationship subsystem, the inter-annual growth of HQDD of other subsystems and HQDL are relatively rapid. These findings can result in the fact that the good performance of water resources plays an important role in promoting high-quality development. Water resources not only maintain ecological balance, but are also necessary for various behaviors and activities of residents [54]. Therefore, when water resources are faced with severe shortages, the process of high-quality development will also be hindered. However, according to He et al. [55], most of these regions are still facing the problem of over-exploitation of water resources, and if they are not improved, the restrictive role of water resources will become increasingly prominent. For the western region with a backward HQDL, the economy, ecology, resources, and human-water relations are all in a backward state in the country, and the western region is also facing constant soil erosion problems [42]. Water scarcity has become one of the important improvement directions for regional development [56]. It can also be found that the higher the development level, the greater constraint of water resources, which shows that as long as the country develops well, water resources will eventually become the biggest constraint factor.

Although water resources have a greater effect on HQDL in developed regions, environmental protection and economic development must not be neglected in regional development. A high-quality environment is one of the sources of happiness. It can be seen from the results that HQD is impossible in areas with poor ecological environment. The improvement of the environment needs sufficient water resources input, and good ecology can improve the environment's capacity of water conservation, such as regulating runoff and purifying water quality. Economic development drives innovation. Technological advances improve patterns of water use and will further promote efficient use of water resources. Sufficient water resources can meet production needs and develop the economy. In the process of HQD in the new era, the country should improve the relationship between human and water in many ways. For example: (1) China should strictly abide by the most stringent water resources management system, and strengthen the construction of water resources management and protection system; (2) Regions promote the connectivity of rivers and lakes to form a reasonable water resource allocation pattern; (3) Beijing and other water-scarce areas should improve the structure and efficiency of water use and improve the water-saving system; (4) Areas rich in water resources should speed up the establishment of water resources protection and river health assurance systems, improve water quality, and effectively restore ecologically fragile rivers and regional ecology; (5) The northwest regions should focus on building water diversion projects to solve water shortage, and increase tree planting to improve water conservation capacity.

6. Conclusions and Policy Implication

6.1. Conclusions

This study achieved the integrated assessment of HQDL in Mainland China by employing a synthetic evaluation-equilibrium analysis two-stage perspective. Specifically, an improved HQDL evaluation system was established considering the constraints of water resources, in which 19 representative indicators from four subsystems were selected. On this basis, the SMI-P method was applied to evaluate the HQDL of 31 PLARs in China, from 2010 to 2019. Moreover, the spatial equilibrium calculation method has been used to calculate the SED of each index and HQD. The main conclusions are:

(1) The HQDL of China's 31 PLARs showed a steady upward trend from 2010 to 2019, and presented a spatial characteristic of decreasing from the coast to the inland, and from the southeast to the northwest; (2) The SED of China's HQD showed a slow upward trend, reached the highest value in 2015, and maintained a relatively stable state after 2015; (3) Water constraints play a significant role in well-developed areas, while the economic and social level is still the main constraint in the medium and poor level areas.

We can find that water resources will eventually become an important constraint when regions develop to a certain level. The timely and sustainable utilization of water resources enables regions to effectively improve HQDL. However, due to difficulties in data acquisition, the study period was selected as 2010–2019, and the effects of water constraints are only evident in some developed provinces. In future studies, it is necessary to expand the study period and adjust corresponding indicators according to data sources. The method adopted in this paper can be applied to different countries and regions. However, the limitation of the calculation method of SED is that the deviation between the factor value of spatial equilibrium participants and the target value of spatial equilibrium is generally subjective, so the method can be improved in future research.

6.2. Policy Implication

China should improve the status of water resources in many ways, and then increase the HQDL. For example: (1) China should strictly implement the most stringent water management system, improve water resources planning for HQD, and promote the Interconnected River System Network; (2) Decision makers should establish water resources and environmental protection plans, constantly improve the legislative system and mechanism, and severely crack down on the unauthorized use and discharge of sewage; (3) The state should encourage the development of science and technology, promote the development of the water conservancy industry, and optimize the construction of the water conservancy system; (4) All river basins should strengthen the environmental management of water source areas to improve the water conservation capacity; (5) All provinces should strengthen exchanges, learn from each other, and make progress together. For regions, water-scarce areas such as Beijing should increase water conservation efforts, improve water use efficiency, and increase investment in environmental and water governance. The western regions need all-round development in multiple fields, improving the economic level, constructing water transfer projects to solve the problem of water shortage, planting trees to improve the ecological environment, and encouraging innovation to improve the efficiency of resource utilization. Areas with abundant water resources should give full play to their advantages, rationally plan and allocate water resources, and determine production based on water, to avoid waste.

Going forward, clarifying the constraint effects of water resource on HQD, looking at how to improve the HQD mode under water resource constraints, realizing the rational allocation of water resources, and building a modern water resource management system, are all worth studying in the future.

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References

1. Jiang, L.; Zuo, Q.T.; Ma, J.X.; Zhang, Z.Z. Evaluation and prediction of the level of high-quality development: A case study of the Yellow River Basin, China. *Ecol. Indic.* **2021**, *129*, 107994. [CrossRef]
2. Simona, T. Emerging Biophilic Urbanism: The Value of the Human–Nature Relationship in the Urban Space. *Sustainability* **2020**, *12*, 5487. [CrossRef]
3. Kroll, C.; Warchold, A.; Pradhan, P. Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies? *Palgrave Commun.* **2019**, *5*, 140–150. [CrossRef]
4. Tian, W.; Li, W.H.; Song, H.F.; Yue, H.D. Analysis on the difference of regional high-quality development in Beijing-Tianjin-Hebei city cluster. *Procedia Comput. Sci.* **2022**, *199*, 1184–1191. [CrossRef]
5. China Center for International Economic Exchanges; Columbia University's Earth Institute; The Ali Institute. *Evaluation Report on the Sustainable Development of China*; Social Sciences Academic Press: Beijing, China, 2020.
6. Cao, J.L.; Ge, C.R. Research on the Impact of Technology Innovation on Quantity and Quality of Economic Growth in the Yangtze River Delta of China: A Comparative Study. *Int. J. Sustain. Dev. Plan.* **2021**, *16*, 1455–1464. [CrossRef]
7. Mlachila, M.; Tapsoba, R.; Tapsoba, S. *A Quality of Growth Index for Developing Countries: A Proposal*; IMF Working Papers; International Monetary Fund: Washington, DC, USA, 2014; Volume 2014, p. 1. [CrossRef]
8. Pan, W.; Wang, J.; Lu, Z.; Liu, Y.S.; Li, Y.R. High-quality development in China: Measurement system, spatial pattern, and improvement paths. *Habitat Int.* **2021**, *118*, 102458. [CrossRef]
9. Aslam, S.; Aftab, H.; Martins, J.M.; Mata, M.N.; Qureshi, H.A.; Adriano, A.M.; Mata, P.N. Sustainable Model: Recommendations for Water Conservation Strategies in a Developing Country Through a Psychosocial Wellness Program. *Water* **2021**, *13*, 1984. [CrossRef]
10. Grimaldi, M.; Pellecchia, V.; Fasolino, I.; Martellozzo, F.; Murgante, B. Urban Plan and Water Infrastructures Planning: A Methodology Based on Spatial ANP. *Sustainability* **2017**, *9*, 771. [CrossRef]
11. Luo, J. Research on the Correlation between Water Resources Utilization and Economic Growth- Based on VAR Model. *World Sci. Res. J.* **2021**, *7*, 32–44. [CrossRef]
12. Wang, W.; Tang, D.; Pilgrim, M.; Liu, J. Water resources compound systems: A macro approach to analysing water resource issues under changing situations. *Water* **2016**, *8*, 2. [CrossRef]
13. Hatamkhani, A.; Shourian, M.; Moridi, A. Optimal Design and Operation of a Hydropower Reservoir Plant Using a WEAP-Based Simulation–Optimization Approach. *Water Resour. Manag.* **2021**, *35*, 1637–1652. [CrossRef]
14. Nava, L.F.; Brown, C.; Demeter, K.; Lasserre, F.; Milanés-Murcia, M.; Mumme, S.; Sandoval-Solis, S. Existing opportunities to adapt the Rio Grande/bravo basin water resources allocation framework. *Water* **2016**, *8*, 291. [CrossRef]
15. Hatamkhani, A.; Moridi, A.; Yazdi, J. A simulation—Optimization models for multi-reservoir hydropower systems design at watershed scale. *Renew. Energ.* **2020**, *149*, 253–263. [CrossRef]
16. Guan, H.P.; Chen, L.H.; Huang, S.P.; Yan, C.; Wang, Y. Multi-objective optimal allocation of water resources based on 'three red lines' in Qinzhou, China. *Water Policy* **2020**, *22*, 541–560. [CrossRef]
17. Avarideh, F.; Attari, J.; Moridi, A. Modelling Equitable and Reasonable Water Sharing in Transboundary Rivers: The Case of Sirwan-Diyala River. *Water Resour. Manag.* **2017**, *31*, 1191–1207. [CrossRef]
18. Moridi, A.; Yazdi, J. Optimal Allocation of Flood Control Capacity for Multi-Reservoir Systems Using Multi-Objective Optimization Approach. *Water Resour. Manag.* **2017**, *31*, 4521–4538. [CrossRef]
19. Yazdi, J.; Moridi, A. Multi-Objective Differential Evolution for Design of Cascade Hydropower Reservoir Systems. *Water Resour. Manag.* **2018**, *32*, 4779–4791. [CrossRef]
20. Jing, Z.R.; Wang, J.M. Sustainable development evaluation of the society–economy–environment in a resource-based city of China:A complex network approach. *J. Clean. Prod.* **2020**, *263*, 121510. [CrossRef]
21. Dang, V.T.; Wang, J.M.; Dang, W.V. An Integrated Fuzzy AHP and Fuzzy TOPSIS Approach to Assess Sustainable Urban Development in an Emerging Economy. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2902. [CrossRef]
22. Sun, Z.; Ma, H. Assessment of the sustainable development of the Beijing-Tianjin-Hebei urban agglomeration based on a back propagation neural network. *Acta Ecol. Sin.* **2018**, *38*, 4434–4444. [CrossRef]
23. Hai, Y.S. Urban Sustainable Development Evaluation Based on System Dynamic Model. *Adv. Mater. Res.* **2012**, *1793*, 518–523. [CrossRef]
24. Bian, D.H.; Yang, X.H.; Wu, F.F.; Babuna, P.; Luo, Y.K.; Wang, B.; Chen, Y.J. A three-stage hybrid model investigating regional evaluation, pattern analysis and obstruction factor analysis for water resource spatial equilibrium in China. *J. Clean. Prod.* **2022**, *331*, 129940. [CrossRef]
25. Chen, W.; Sun, W.; Zhao, H.X. The spatial imbalanced pattern and state assessment of regional development. *Acta Geogr. Sin.* **2010**, *65*, 1209–1217. (In Chinese)
26. Lu, D.D. The development of economic geography and its function on strategy consultation. *Econ. Geogr.* **2011**, *31*, 529–535. (In Chinese) [CrossRef]
27. Zuo, Q.T.; Han, C.H.; Ma, J.X.; Wang, X. Theoretical Method and Applied Research Framework of Water Resources Spatial Equilibrium. *Yellow River* **2019**, *41*, 113–118. (In Chinese) [CrossRef]
28. Chen, M.; Lu, D.; Tang, Z.P.; Lu, D.D.; Liu, H.; Ma, L. The provincial pattern of the relationship between urbanization and economic development in China. *J. Geogr. Sci.* **2014**, *24*, 33–45. [CrossRef]

29. Chen, Y.P.; Fu, B.J.; Zhao, Y.; Wang, K.B.; Zhao, M.M.; Ma, J.F.; Wu, J.H.; Xu, C.; Liu, W.G.; Wang, H. Sustainable development in the Yellow River Basin: Issues and strategies. *J. Clean. Prod.* **2020**, *263*, 121223. [CrossRef]
30. Xu, Z.; Chau, S.N.; Chen, X.Z.; Zhang, J.; Li, Y.J.; Thomas, D.; Wang, J.Y.; Winkler, J.A.; Fan, F.; Huang, B.R.; et al. Assessing progress towards sustainable development over space and time. *Nature* **2020**, *577*, 74–78. [CrossRef]
31. Huang, T.H.; Zhao, X.Y.; Ai, C.H.; Chen, S.F.; Wang, Y.; Hu, X.Y. Evaluation of the sustainable development level of countries along the Belt and Road and its impact factors: Empirical analysis based on the Super-efficiency slacks-based measure and Tobit measure models. *Chin. J. Popul. Resour.* **2021**, *19*, 162–170. [CrossRef]
32. Xu, G.H.; Ge, Q.S.; Gong, P.; Fang, X.Q.; Cheng, B.B.; He, B.; Luo, Y.; Xu, B. Societal response to challenges of global change and human sustainable development. *Chin. Sci. Bull.* **2013**, *58*, 3161–3168. [CrossRef]
33. Liao, H.X.; Ji, Y.L.; Peng, S.L. Resource and environment carrying capacity and sustainable development. *Ecol. Environ. Sci.* **2016**, *25*, 1253–1258.
34. Halleröd, B.; Seldén, D. The Multi-dimensional Characteristics of Wellbeing: How Different Aspects of Wellbeing Interact and Do Not Interact with Each Other. *Soc. Indic. Res.* **2013**, *113*, 807–825. [CrossRef]
35. Zuo, Q.T.; Chen, H.; Dou, M.; Zhang, Y.Y.; Li, D.F. Experimental analysis of the impact of sluice regulation on water quality in the highly polluted Huai River Basin, China. *Environ. Monit. Assess.* **2015**, *187*, 1–15. [CrossRef] [PubMed]
36. Luo, Z.L.; Zuo, Q.T. Evaluating the coordinated development of social economy, water, and ecology in a heavily disturbed basin based on the distributed hydrology model and the harmony theory. *J. Hydrol.* **2019**, *574*, 226–241. [CrossRef]
37. Yang, J.Y.; Zhang, L.L. Fuzzy Comprehensive Evaluation Method on Water Environmental Quality Based on Entropy Weight with Consideration of Toxicology of Evaluation Factors. *Adv. Mater. Res.* **2011**, *356–360*, 2383–2388. [CrossRef]
38. Qiu, M.; Yang, Z.L.; Zuo, Q.T.; Wu, Q.S.; Jiang, L.; Zhang, Z.Z.; Zhang, J.W. Evaluation on the relevance of regional urbanization and ecological security in the nine provinces along the Yellow River, China. *Ecol. Indic.* **2021**, *132*, 108346. [CrossRef]
39. Zuo, Q.T.; Han, C.H.; Ma, J.X. Application rules and quantification methods of water resources spatial equilibrium theory. *Hydro-Sci. Eng.* **2019**, *6*, 50–58. (In Chinese) [CrossRef]
40. National Bureau of Statistics of the People's Republic of China. *China Statistical Yearbook on Environment*; China Statistics Publishing House: Beijing, China, 2021.
41. Wei, X.X.; Shen, L.Y.; Liu, Z.; Luo, L.Y.; Wang, J.H.; Chen, Y. Comparative analysis on the evolution of ecological carrying capacity between provinces during urbanization process in China. *Ecol. Indic.* **2020**, *112*, 106179. [CrossRef]
42. Zhang, F.; Xing, Z.S.; Zhao, C.Y.; Deng, J.L.; Yang, B.; Tian, Q.; Rees, W.H.; Badreldin, N. Characterizing long-term soil and water erosion and their interactions with various conservation practices in the semi-arid Zulihe basin, Dingxi, Gansu, China. *Ecol. Eng.* **2017**, *106*, 458–470. [CrossRef]
43. Xiang, X.; Kong, L.; Sun, H.; Lei, X.; Liang, J.; Li, Y. Recent Developments in the Application of Water Resource Dispatching Systems in China. *Water* **2021**, *13*, 26. [CrossRef]
44. Wang, Z.; Xu, Y.; Zhang, Z.; Zhang, Y. Review: Acid Mine Drainage (AMD) in Abandoned Coal Mines of Shanxi, China. *Water* **2021**, *13*, 8. [CrossRef]
45. Jia, J.X.; Ma, G.R.; Qin, C.; Wang, L.Y. Place-based policies, state-led industrialisation, and regional development: Evidence from China's Great Weste Development Programme. *Eur. Econ. Rev.* **2020**, *123*, 103398. [CrossRef]
46. Liu, S.Y.; Zhang, F.Z.; Wu, F.L. Contrasting migrants' sense of belonging to the city in selected peri-urban neighbourhoods in Beijing. *Cities* **2022**, *120*, 103499. [CrossRef]
47. Eheliyagoda, D.; Li, J.H.; Geng, Y.; Zeng, X.L. The role of China's aluminum recycling on sustainable resource and emission pathways. *Resour. Policy* **2022**, *76*, 102552. [CrossRef]
48. Zhang, M.; Wang, L.J.; Ma, P.P.; Wang, W.W. Urban-rural income gap and air pollution: A stumbling block or stepping stone. *Environ. Impact Asses.* **2022**, *94*, 106758. [CrossRef]
49. Kuang, Y.M.; Lin, B.Q. Public participation and city sustainability: Evidence from Urban Garbage Classification in China. *Sustain. Cities Soc.* **2021**, *67*, 102741. [CrossRef]
50. Zhang, J.X.; Zhang, N.; Bai, S.X. Assessing the carbon emission changing for sustainability and high-quality economic development. *Environ. Technol. Innov.* **2021**, *22*, 101464. [CrossRef]
51. KhazaiPoul, A.; Moridi, A.; Yazdi, J. Multi-Objective Optimization for Interactive Reservoir-Irrigation Planning Considering Environmental Issues by Using Parallel Processes Technique. *Water Resour. Manag.* **2019**, *33*, 5137–5151. [CrossRef]
52. Moridi, A.; Yazdi, J. Sediment Flushing of Reservoirs under Environmental Considerations. *Water Resour. Manag.* **2017**, *31*, 1899–1914. [CrossRef]
53. Zhu, D.M.; Chang, Y.J. Urban water security assessment in the context of sustainability and urban water management transitions: An empirical study in Shanghai. *J. Clean. Prod.* **2020**, *75*, 122968. [CrossRef]
54. Meng, X.M.; Tu, L.P.; Yan, C.; Wu, L.F. Forecast of annual water consumption in 31 regions of China considering GDP and population. *Sustain. Prod. Consump.* **2021**, *27*, 713–736. [CrossRef]
55. He, Y.H.; Lin, K.R.; Zhang, F.; Wang, Y.L.; Chen, X.H. Coordination degree of the exploitation of water resources and its spatial differences in China. *Sci. Total Environ.* **2018**, *644*, 1117–1127. [CrossRef] [PubMed]
56. Li, D.L.; Zuo, Q.T.; Zhang, Z.Z. A new assessment method of sustainable water resources utilization considering fairness-efficiency-security: A case study of 31 provinces and cities in China. *Sustain. Cities Soc.* **2022**, *81*, 103839. [CrossRef]