Water Security Assessment of China's One Belt and One Road Region

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Abstract: The sustainable development of socioeconomic and environmental systems are highly dependent on water capital and water utilization efficiency. Nowadays, a significant portion of the world is facing water security issues due to a combination of various factors. As a result, socioeconomic and environmental systems are threatened. China is also currently experiencing problems. Water security assessment helps to identify key determining factors for optimal water utilization, so the authors present the Driving Forces-Pressures-Carrying Capacity-State-Impacts-Responses (DPSCIR) water security assessment framework. Unlike previous methods, the proposed framework incorporates the carrying capacity of the environment, and as a result, yields assessment results that are more realistic. As a case study, the proposed framework coupled with the entropy method is applied to assess the water security status of the One Belt and One Road (B&R) region in China. In addition, the water security level of the provinces and municipalities in this region are simulated for the time period from 2017 to 2022 using the Grey Prediction Model. The results show that Responses, State, Pressures, and Carrying Capacity Subsystems greatly influence water security of the region. According to the assessment, water security of the area improved from 2011 to 2016. The results portray the following trend among the three subregions of the study area, the water security of the 21st Maritime Silk Road (One Road) area is better than Silk Road Economic Belt (One Belt) and the Strategy Support and Pivotal Gateway (SSPG) of B&R areas. Generally, from the evaluation results it can be concluded that only focusing on the subsystem of Responses cannot entirely address the water security problems within the B&R area. Therefore, to ensure sustainable water security in the region and in the country, the government needs to design water resource management mechanisms that take all the subsystems into account.

Keywords: One Belt and One Road; water resource security; DPCSIR model; entropy weight method

1. Introduction

Currently, different parts of the world are facing serious water scarcity challenges [1]. The Middle East and South Asia are typical examples [2]. In 1962 and 2014, freshwater availability per capita throughout the world was 13,360.32 m^3 and 5925.67 m^3, respectively [3]. This shows a decrease of

almost 1500 m^3 every ten years. With the growing population, more water will be needed to produce the estimated 60% of the extra food needed by 2050 [4]. This is seriously increasing the vulnerability of socioeconomic and ecological systems' changes in water quantity and quality [5]. Uneven temporal and spatial distribution of water resources is the main cause of water shortage. This case is no different in China. As a result, even though water is abundant in China, the per capita water availability is only 2061 m^3. The country ranked 125th in terms of per capita water availability in the world [6]. Hence, water resource management studies are highly encouraged in order to obtain insights that can be used to improve the country's water security status.

Assessing water scarcity can be one of the ways to obtain insights into the water security of an area [7]. Most of the previous studies on water scarcity evaluate water scarcity as demand- or population-driven [8,9]. Thus, at present, popular understandings of water scarcity are based on water insufficiency [10]. Quantifying the water issues only with these determining parameters might not help us to understand the real reasons behind water scarcity, such as water mismanagement [11,12] and uneven water distribution due to economic reasons or environmental factors [13,14]. It is only when we have an accurate understanding of the reasons behind water scarcity that appropriate solutions can be designed and implemented [15]. This is why assessing water security is useful. Assessing water security will capture the issues associated with water in a broader context than water scarcity.

Many scholars have carried out a large number of studies on water security. The concept of water security originated in the 1940s and has undergone through three phases [16] and is still a changing concept [17,18]. Water security is defined as sustainable utilization of water resources, adequate in both quantity and quality, for human well-being, socio-economic development, and ecological conservation, including an acceptable level of risk of water-related disasters [19–24]. A comprehensive water security assessment is critical to sustainable water management [25]. It can be used to design adaptive water management regimes. Therefore, a water security assessment is one of the main components of any comprehensive water resource management [26,27] and assessing the status of water security is one of the topics that needs to be investigated first. Water security assessments assist to ascertain a general picture of the issues that require an all-encompassing solution [28]. Research on water security assessments mainly involves water-related risks [29], water-poverty [30], water-vulnerability [31,32], and water security governance [33]. Water security problems have a complex nature which is rooted not only in the availability of freshwater resources relative to water demand, but also on social and economic factors [34]. For example, Vörösmarty (2010) [35] appraised the threat of human activities and biodiversity dangers which are being affected from water insecurity by considering: 23 indicators, including catchment disturbance, pollution, water resource development, and biotic factors. Lautze and Manthrithilake (2012) [36] assessed water security by considering five critical dimensions (i.e., basic needs, agricultural production, the environment, risk management, and independence) for 46 countries in the Asia–Pacific region. Sustainable Development Goal (SDG) 6 [37] provides a good base for water security indicators selection. However, there is still room for improvement. It is not advisable to completely apply the SDG 6 indicators into the assessment framework of water security [38,39]. Hence, SDG 6 indicators need to be combined with specific goals, which will guide our indicators selection.

As for methods used to assess water security, the most common evaluation models are the SES-Model [40], Water GAP3 model [4], system dynamics model [41], and DPSIR model [42]. The Driving Forces-Pressures-Carrying Capacity-State-Impacts-Responses (DPCSIR) [43,44] framework is developed based on the DPSIR model. Compared to other methodologies, the DPCSIR framework [45] can take socioeconomic activities and the ecosystem into account to produce better results. Both methodological frameworks can be applied to identify the factors that threaten water security. However, the DPSIR model has two flaws in the assessment of water security. Firstly, even though it considers the impact of human social and economic activities on the water environment when reflecting the causes of water security problems, it does not take into account the Carrying Capacity of the environment. It is worth noting that in the analysis of regional water security problems, not all water security problems come from human activities but may also come from changes in the ecological environment itself.

Secondly, the model is not comprehensive enough to take into account the interactions between social and economic factors, and the environment. This might ultimately lead to inaccurate results of water resources security assessment.

To fill these research gaps, we use the DPCSIR model to build a water security assessment index. In addition, most previous studies are focused on assessing the water security status for a target year rather than carrying out a dynamic time series assessment. In this article, the authors use the entropy method to calculate the weights of the different determining factors, and carry out a comprehensive water security assessment and prediction of China's B&R Region using the DPCSIR model. The insights for the article might help policymakers understand and identify current water security issues in the study area. Furthermore, based on the assessment, possible courses of action to mitigate water insecurity problems are forwarded.

This paper is organized into four parts. Section 1 is stated above. Section 2 introduces the materials and methods. Section 3 presents the results and discussion and finally, the conclusions and recommendations are provided in Section 4.

2. Materials and Methods

2.1. Study Area

One Belt and One Road (B&R) is China's most important development initiative. It is one of the three main economic development strategies in China. The B&R initiative is an international and regional cooperation initiative proposed by President Xi Jinping of China during his visit to central Asian and Southeast Asian countries in 2013 [46]. It is an initiative of trans-regional cooperation promoting common economic development and enhancing China's contribution to global sustainable development. The initiative covers a large surface area compared to the country's other strategies. Its land-cover accounts for 77.83% of the whole country. Its GDP was 5324.59 US billion dollars, accounting for 47.53% of China's total GDP in 2016. The urbanization rate of the B&R area in China was 57.21%, lower than the urbanization rate in China's developed regions, such as Shanghai (87.9%) [47], which indicated the region still has development potential. It includes 5895.4 million people (42.64% of China's population) and is home to various resources and intensive economic sectors.

In order to implement the initiative, the Chinese government has formulated special plans for the 18 provinces and municipalities in China included in the initiative [48]. This is because these areas are now facing over-exploitation, severe pollution, and resource shortages. Most of these areas lie on the country's borders. One of the challenges of these areas is their declining water security level. The water consumption in this area had increased from 290.0 billion m^3 in 2003 to 328.3 billion m^3 in 2016, and the growth rate reached 13.14%. Hence, the water resource demand of the region is huge and shows an increasing trend. Therefore, how to guarantee the water security of the area to promote sustainable economic growth has become an urgent issue to be addressed.

At present, most of the research on the B&R initiative focuses on different topics, such as politics, industry guidance, and policy implementation [49–54]. However, there is a lack of study focusing on water security in the part of the region covered by the initiative within China. Water insecurity might hinder China's sustainable development and pose a serious risk to the implementation of the B&R initiative. Hence, carrying out a systematic water security assessment of the provinces and municipalities of China within the B&R helps to identify the water security problems and put forward effective solutions.

The B&R initiative consists of 18 provinces and municipalities in China. It is divided into three regions according to their geographic location (see Figure 1). The Silk Road Economic Belt (One Belt) includes Inner Mongolia, Liaoning, Jilin, Heilongjiang, Xinjiang, Shaanxi, Gansu, Ningxia, and Qinghai, while Shanghai, Fujian, Guangdong, Zhejiang, and Hainan are located in the 21st Maritime Silk Road (One Road). The Strategy Support and Pivotal Gateway of One Belt and One Road Initiative area (SSPG area) includes Guangxi, Yunnan, Tibet, and Chongqing.

Figure 1. One Belt and One Road region's 18 provinces and municipalities in China.

2.2. Methods

2.2.1. The DPCSIR Model

The Driving Forces-Pressures-State-Carrying Capacity-Impacts–Responses (DPCSIR) model was proposed by Wang et al. (2011) [45]. This framework is developed from the PSR and DPSIR models [55,56]. The reason why we use the DPCSIR framework to assess comprehensive water security is that it takes into account the causal chain caused by environmental problems and considers population growth and social and economic development as long-term Driving Forces to investigate the pressures on the environment as well as the feedback effect caused by environmental changes. This will help us to understand the causal relationship and influence between economic activities and the environment at different scales.

The interrelationship between the subsystems of the DPCSIR models is shown in Figure 2. Driving Forces are the socio-economic factors that drive human activities, which raise or mitigate pressures on ecosystems. Pressures are the impact of human activities on the environment. The Carrying Capacity reflects the capacity of the environment to support human activities. The State subsystem represents the current status of the environment. Impacts are the effect of environmental deterioration. Responses refer to the reactions by society to address environmental issues.
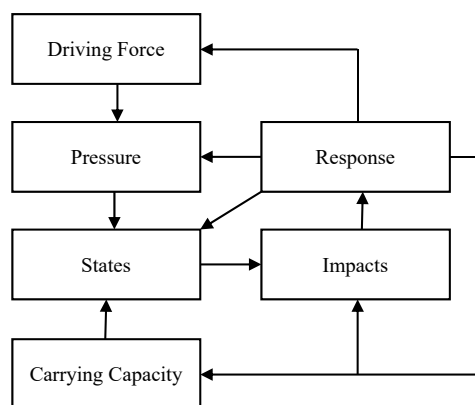

Figure 2. Driving Forces-Pressures-State-Carrying Capacity-Impacts–Responses (DPCSIR) model.

2.2.2. The Entropy-Weighted Method

Based on the chosen indicators, water security can be measured as follows:
The first step is data standardization.

$$\text{Positive indicators}: \ X_{ij} = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \tag{1}$$

$$\text{Negative indicators}: \ X_{ij} = \frac{x_{\max} - x_i}{x_{\max} - x_{\min}} \tag{2}$$

where X_{ij} is the normalized value; X_i is the original value; $X_{\max}$ is the maximum value; and $X_{\min}$ is the minimum value of the corresponding factor.

The second step is the calculation of the weights. The entropy method is based on Shannon Entropy [57] and is used to calculate the weights [58,59]. The concept of entropy is born from information theory, which is a measure of uncertainty. The entropy method has been widely used because it can objectively calculate the weight of assessment factors. If the factor is considered to be important, it will be given a higher weight coefficient.

The detailed procedures for the entropy method are as follows:
(1) Calculating the proportion f_{ij} of the index value in the i year for the index item j.

$$f_{ij} = \frac{X_{ij}}{\sum\limits_{i=1}^{m} X_{ij}}, (j = 1, 2, \ldots, n) \tag{3}$$

where m is the number of years; n is the number of evaluation indicators.
(2) The entropy e_j of the j index can be determined as follows:

$$e_j = \frac{\sum\limits_{i=1}^{m} f_{ij} \ln f_{ij}}{\ln m} \tag{4}$$

(3) After the entropy value of the index is determined, the weight of the index ω_j can be computed as follows.

$$\omega_j = \frac{1 - e_j}{n - \sum\limits_{j=1}^{n} e_j} \tag{5}$$

The third step is the calculation of water security level.

$$f(J) = \sum\limits_{j=1}^{n} X_{ij} \cdot \omega_j \tag{6}$$

2.2.3. Classical Grey Prediction Model

The Grey Prediction Model [60] is often used to process data and establish a Grey Model to make a quantitative prediction of a future development trend. It has shown excellent ability in solving problems for which effective information is incomplete and uncertain and this can proceed with correlation analysis by identifying the development trend and degree of difference between system factors. Therefore, it is widely used in numerical prediction [61–63]. The Grey Prediction Model is used to predict the water security for the time period from 2017 to 2022. The specific steps are as follows:

Let $X^{(0)} = \left\{ x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(N) \right\}$ be the original sequence, and $X^{(1)} = \left\{ x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(N) \right\}$ be the new sequence, then the new sequence need satisfy $x^{(1)}(t) = \sum_{k=1}^{t} x^{(0)}(k)$.

Step 1: Construct the cumulative data matrix B and a constant term vector Y.

$$B = \begin{bmatrix} -\frac{1}{2}(x^{(1)}(1) + x^{(1)}(2)) \\ -\frac{1}{2}(x^{(1)}(2) + x^{(1)}(3)) \\ \vdots \\ -\frac{1}{2}(x^{(1)}(N-1) + x^{(1)}(N)) \end{bmatrix} \tag{7}$$

$$Y = \left[x_1^{(0)}(2), x_1^{(0)}(3), \ldots, x_1^{(0)}(N) \right]^T \tag{8}$$

Step 2: Calculate the parameters a and b.

$$\alpha = \begin{bmatrix} a \\ b \end{bmatrix} = \left(B^T B \right)^{(-1)} B^T Y \tag{9}$$

Step 3: Put the parameters a and b into the equation.

$$x^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a} \right] e^{-\alpha t} + \frac{b}{a} \tag{10}$$

Step 4: Calculate the simulation value: $x^{(0)}(k)$.

$$x^{(0)}(k) = x^{(1)}(k) - x^{(1)}(k-1) \tag{11}$$

Step 5: Calculate the average relative error ($\bar{\varepsilon}$), variance ratio (c), small error probability and test the simulation value. $x\Lambda^{(0)}(t)$ is the simulation value of the model, $\varepsilon^{(0)}(t)$ is the relative error, s_1 is a standard deviation of the original sequence $X^{(0)}$, and s_2 is the standard deviation of relative sequence $\varepsilon^{(0)}(t)$, c represents the residual probability.

$$\text{The relative error}: \ \varepsilon^{(0)}(t) = x^{(0)}(t) - x\Lambda^{(0)}(t) \tag{12}$$

$$\text{The average relative error}: \ \bar{\varepsilon} = \frac{1}{n} \sum_{t=1}^{n} \varepsilon^{(0)}(t) \tag{13}$$

$$\text{The variance ratio}: \ c = \frac{s_2}{s_1} \tag{14}$$

$$s_2^2 = \frac{1}{n} \sum_{t=1}^{n} \left(\varepsilon^{(0)}(t) - \bar{\varepsilon} \right)^2 \tag{15}$$

$$s_1^2 = \frac{1}{n} \sum_{t=1}^{n} \left(x^{(0)}(t) - \bar{x} \right)^2 \tag{16}$$

$$\text{The small error probability}: \ P = p\left\{ \left| \varepsilon^{(0)}(t) - \bar{\varepsilon} \right| < 0.6745 S_1 \right\} \tag{17}$$

In order to ensure the accuracy of the prediction results, the Grey Prediction Model must meet the conditions shown in Table 1 [63] below.

Table 1. Grey Prediction Model's precision standard.

Grade	Relative Error	Variance Ratio	Small Error Probability
Good ***	<0.01	<0.35	>0.95
Qualified **	<0.05	<0.5	>0.80
Inadequate *	<0.20	<0.65	>0.70
Unqualified	≥0.2	≥0.65	≥0.70

Note: ***, **, and * denote the level of grade about good, qualified, and inadequate.

2.2.4. Reliability Analysis

Cronbach's Alpha coefficient is used to analyze the reliability of the built assessment framework [60]. It's crucial that the processed data is standardized and has a higher reliability coefficient. This will ensure the high credibility of the index. We followed De Vellis's [64] test to present the results. The coefficient α ranges are 0.60–0.65 (not preferable), 0.65–0.7 (acceptable value), 0.70–0.80 (pretty good), 0.80–0.90 (very good).

$$\alpha = \frac{k(\overline{\mathrm{cov}}/\overline{\mathrm{var}})}{1 + (k-1)(\overline{\mathrm{cov}}/\overline{\mathrm{var}})} \tag{18}$$

2.3. Indicator Selection and Data Source

The indicators are selected based on the scope of each subsystem and existing literature [65–67]. Considering the principles of representation, hierarchy, and ease of using the data, 30 relevant indicators are selected to build the water security assessment framework in this paper. The data used in this article is mainly from the official yearbooks (see Table 2).

Table 2. The sources of the indicators.

China Statistics Yearbook (2011–2016) [68]	GDP growth rate, Engel coefficient, population growth rate, per capita cultivated land area, per capita water resources, proportion of the added value of tertiary industry
China City Statistical Yearbook (2011–2016) [69]	Population density, urbanization rate, the proportion of science and technology expenditure, the proportion of environmental protection expenditure, per capita net income (Yuan) of urban residents
China Urban-Rural Construction Statistical Yearbook (2011–2016) [70]	Length of water supply pipe, treatment capacity of urban sewage treatment plants, urban sewage treatment rate
China Statistic Yearbook on Environment (2011–2016) [71]	The utilization rate of water resource development, wetland area, annual precipitation, forest coverage rate, green coverage rate of built-up areas, effective irrigation area, chemical oxygen demand, ammonia nitrogen discharge
China Water Resources Bulletin (2011–2016) [47]	Water consumption of ten thousand Yuan output value, discharge of industrial waste-water from ten thousand Yuan output value, daily water supply capacity, daily water consumption per capita, agricultural water consumption, industrial water consumption, ecological environment water consumption, saving water consumption

3. Results and Discussion

3.1. Reliability Analysis and Entropy Weights

Reliability analysis of the assessment framework containing the 30 indicators is obtained using SPSS 22 (Han, 2015) [60]. The results show the Cronbach's Alpha of the 30 factors is 0.730 which indicates that the processed data has high reliability. Therefore, these selected factors can objectively reflect the water security status of the study area.

According to the relative importance of each factor, the judgment matrix is constructed, and the weighted value of each index is determined by entropy (see Table 3).

Table 3. The weights of indicators for the water assessment framework.

Target Layer	Factor Layer	Criterion Layer	IdentIfier	Index Layer	Character	Entropy Weights
"One Belt and One Road" of China regional DPCSIR model water resource security index system	Driving Forces (0.1632)	Economic drive	D_1	GDP growth rate (%)	Positive	0.0329
			D_2	Population density (person /km2)	Negative	0.0339
			D_3	Per capita net income (Yuan) of urban residents	Positive	0.0343
			D_4	Engel coefficient (%)	Negative	0.0321
			D_5	Population growth rate (%).	Negative	0.0299
	Pressures (0.1684)	Resource consumption	P_1	Water consumption of ten thousand Yuan output value (10^4 t)	Negative	0.0345
			P_2	The utilization rate of water resource development (%)	Negative	0.0341
		Environmental pollution	P_3	Discharge of industrial waste-water from ten thousand Yuan output value (t)	Negative	0.0343
			P_4	Chemical oxygen demand (10^4 t)	Negative	0.0326
			P_5	Ammonia nitrogen discharge (10^4 t)	Negative	0.0329
	Carrying Capacity (0.1659)	Environmental quality	C_1	Effective irrigation area (hm^2),	Positive	0.0335
			C_2	Per capita cultivated land area (hm^2)	Positive	0.0342
			C_3	Per capita water resources (t)	Positive	0.0340
			C_4	Wetland area (hm^2)	Positive	0.0302
			C_5	Annual precipitation (mm)	Positive	0.0341
	State (0.1692)	Resources reserve	S_1	Daily water supply capacity (t)	Positive	0.0345
			S_2	Daily water consumption per capita (t)	Negative	0.0340
			S_3	Agricultural water consumption (t)	Negative	0.0335
			S_4	Industrial water consumption (t)	Negative	0.0336
			S_5	Ecological environment water consumption (t)	Positive	0.0336
	Impacts (0.1323)	Social life	I_1	Urbanization rate (%)	Positive	0.0341
			I_2	Forest coverage rate (%)	Positive	0.0304
			I_3	The proportion of the added value of tertiary industry (%)	Positive	0.0330
			I_4	The green coverage rate of built-up areas (%)	Positive	0.0348
	Responses (0.2010)	Governance and consolidation	R_1	Saving water consumption (%)	Positive	0.0325
			R_2	Urban sewage treatment rate (%)	Positive	0.0334
			R_3	Treatment capacity of urban sewage treatment plants (10^4 t/d)	Positive	0.0339
			R_4	Length of water supply pipe (km)	Positive	0.0335
		Economic input	R_5	The proportion of environmental protection expenditure (%)	Negative	0.0337
			R_6	The proportion of science and technology expenditure (%)	Negative	0.0335

3.2. Comprehensive Water Security Analysis of China's B&G Region

Generally, the results show that the water security level of the 18 provinces and municipalities in the B&R region has improved by various degrees within the past 6 years. According to our water security assessment, the One Road area is slightly doing better than the other two regions. Fujian, Heilongjiang, Jilin, Guangxi, and Inner Mongolia have all experienced faster water security growth rates and achieved growth rates of over 19.00% (See Table 4). It's worth noting that the average water security value for 2011 was much lower than that of 2016, which indicated that the B&R China's regional water resources ecosystem was seriously damaged and its sustainable development capacity was significantly weakened in 2011. The main reasons for this phenomenon were that China experienced large-scale, multiple, and severe floods and droughts in 2010 [72], which had a negative impact on the water security index in 2011. Therefore, the water security index in 2011 was relatively

low. On the other hand, the Chinese government began to implement the strictest water resource management system and water ecological civilization construction since 2012 and the water security assessment showed an increasing trend year by year.

Table 4. The evaluation of water resource security index of China's "One Belt and One Road" region from 2011 to 2016.

Regional Division	Provinces and Municipalities	2011	2012	2013	2014	2015	2016	Average Annual Growth Rate (AAGR)	Ranking (AAGR)	Mean Value (MV)	Ranking (MV)
One Belt Area	Inner Mongolia	0.2510	0.4280	0.5131	0.5494	0.5888	0.6050	19.23%	5	0.4892	9
	Liaoning	0.2710	0.4566	0.6078	0.5262	0.6167	0.6204	18.02%	7	0.5165	2
	Jilin	0.2470	0.3847	0.4598	0.4568	0.5409	0.7491	24.85%	3	0.4730	18
	Heilongjiang	0.1933	0.3574	0.5418	0.5422	0.6020	0.6777	28.52%	2	0.4857	11
	Shanxi	0.3641	0.3772	0.4336	0.5180	0.6013	0.6292	11.56%	16	0.4872	10
	Gansu	0.3081	0.3855	0.5315	0.5278	0.5722	0.6331	15.49%	12	0.4930	7
	Qinghai	0.2996	0.4442	0.4445	0.5396	0.5415	0.6438	16.53%	11	0.4855	12
	Ningxia	0.2887	0.3924	0.5110	0.5320	0.5606	0.6280	16.82%	10	0.4855	13
	Xinjiang	0.3361	0.3727	0.5535	0.4592	0.5543	0.6678	14.72%	14	0.4906	8
One Road Area	Shanghai	0.3532	0.4025	0.4106	0.5313	0.6208	0.7154	15.16%	13	0.5056	4
	Zhejiang	0.2857	0.4198	0.4585	0.5564	0.6190	0.6806	18.96%	6	0.5033	5
	Fujian	0.1957	0.3687	0.4918	0.5270	0.5588	0.7238	29.90%	1	0.4776	16
	Guangdong	0.3133	0.3686	0.5131	0.4614	0.5139	0.6905	17.12%	8	0.4768	17
	Hainan	0.4178	0.4466	0.5704	0.5004	0.4677	0.7187	11.46%	17	0.5203	1
SSPG Area	Guangxi	0.2642	0.4124	0.4974	0.5910	0.6408	0.6427	19.46%	4	0.5081	3
	Chongqing	0.3439	0.3884	0.4525	0.5359	0.5213	0.6253	12.70%	15	0.4779	15
	Yunnan	0.3184	0.3607	0.4490	0.4786	0.5879	0.6983	17.01%	9	0.4821	14
	Tibet	0.3665	0.4872	0.4897	0.5146	0.5376	0.6083	10.66%	18	0.5007	6

　　　The overall water security trend shows the One Belt area is better than the SSPG area, and the SSPG area is better than the One Road area. Provinces and municipalities, such as Hainan, Liaoning, Guangxi, Shanghai, Zhejiang, and Tibet, have a score that exceeded 0.5 (See Table 4 and Figure 3). We observe that most provinces and municipalities have attached great importance to water resource security in the past few years and achieved remarkable results through continuous improvement by increasing technological investment focusing on water use efficiency and decommissioning of backward production facilities with a high water footprint. This result concurs with the research done by Tan (2016) [73]. The research showed that the average of regional comprehensive water efficiency of the One Belt area and the SSCG area had been increasing during the time period from 2000–2013. Inner Mongolia, Heilongjiang, and Jilin achieved a higher ranking than other provinces and municipalities.

　　　From assessing the water security status of specific provinces and municipalities, it can be seen that Liaoning, Jilin, and Heilongjiang in the One Belt region have benefited from having a good economic and technological foundation, as a result, their overall water security is relatively better. However, in recent years, the progress of water resource protection initiatives is comparatively not significant due to slow economic development and insufficient technological progress. Some provinces in the area, such as Inner Mongolia, Shanxi, Gansu, Qinghai, Ningxia, and Xinjiang, ranked far behind in terms of their water security status. This is mainly due to low water capital and slow economic development. Furthermore, the lack of sufficient attention to this problem affects the score of the Responses subsystem, leading to the low water security improvement rate. Our results concur with Zuo [74]. We observe that most of the provinces and municipalities of water insecurity are located in geographical areas with low precipitation, high population density, and slow economic development.

　　　However, rapid economic development may also lead to water security problems. Sometimes it is hard to balance economic development and environmental sustainability [75]. For instance, even though Guangdong and Fujian have better-developed economies within the B&R area of China, with

GDP ranked 1st and 3rd in 2016 [71], their water security level is relatively low. One reason for this situation is that water resource management efforts have been insufficient. This results in low water resource utilization efficiency and high environmental pollution. Another reason is the "resource curse" which makes people who live in regions of high water availability less sensitive to water saving schemes [76]. The average annual growth rate of water security for Fujian and Guangdong is relatively high, ranked the first and the eighth respectively. Hence, water security has a great prospect for improvement. The Strategy Support and Pivotal Gateway of the B&R area containing Guangxi, Tibet, and Yunnan have better water security, while Chongqing's is not that good. Chongqing needs to promote water saving measures to improve its water security.

Although the overall water security assessment shows a growing trend from 2011–2016, it obscures nonlinear growth. This is a reason why the marginal growth rate analysis is needed to show these changes. Looking at the marginal growth rate (see Appendix A Table A2), the annual marginal growth rate of various provinces and cities has shown different declining trends, which means that it will be increasingly difficult to improve the water security level in the following years. The marginal rate of Liaoning, Guangdong, Hainan, and Xinjiang in 2014 had a larger degree of decline, the decline rate was 13.43%, 10.01%, 12.26%, and 17.04%, respectively. In order to study the reasons for this phenomenon, we calculate the marginal growth rate of each index in the above four provinces and screen out the impact indicators that cause the marginal growth rate to decrease greatly and rank them according to the influence of the weight of the six subsystems (See Appendix A Table A3). In summary, fewer Responses to water ecological protection, weakened the Carrying Capacity, the continuous growth of water consumption and sewage discharge, and the slowing economic development lead to this nonlinear phenomenon, thus it is necessary to maintain the sustainability of water security protection policies.
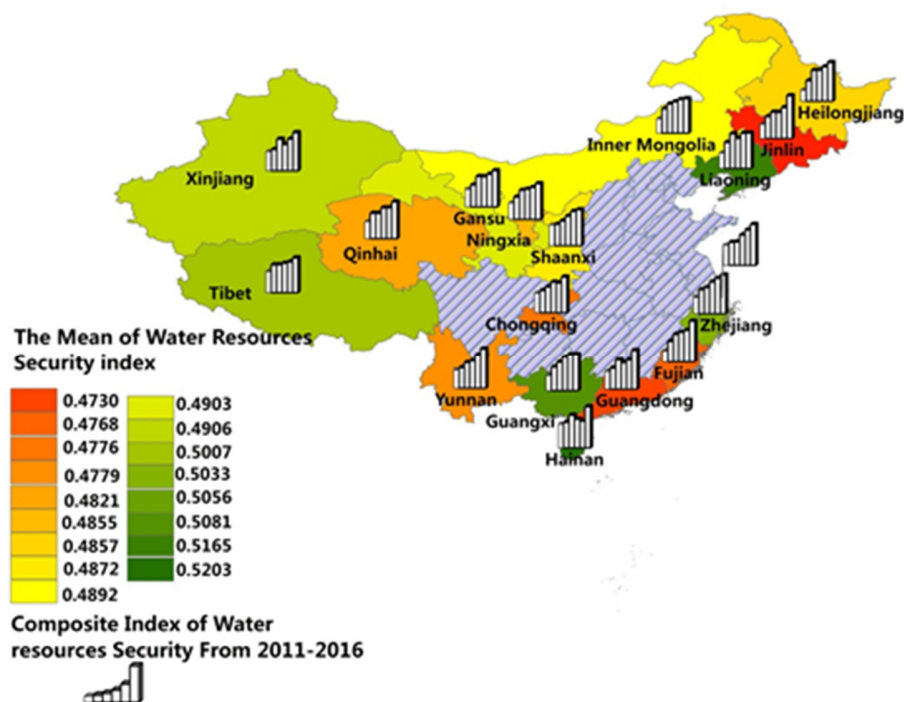

Figure 3. Water security level of the One Belt and One Road region in China.

3.3. Subsystem Assessment

The result shows that the subsystems of Responses, State, Pressures, and Carrying Capacity have the greatest effect on water security. Each subsystem has different impacts on water resources in various provinces and municipalities. The weight of each subsystem is determined by the entropy method (see in Appendix A Table A1 and Figure 4).
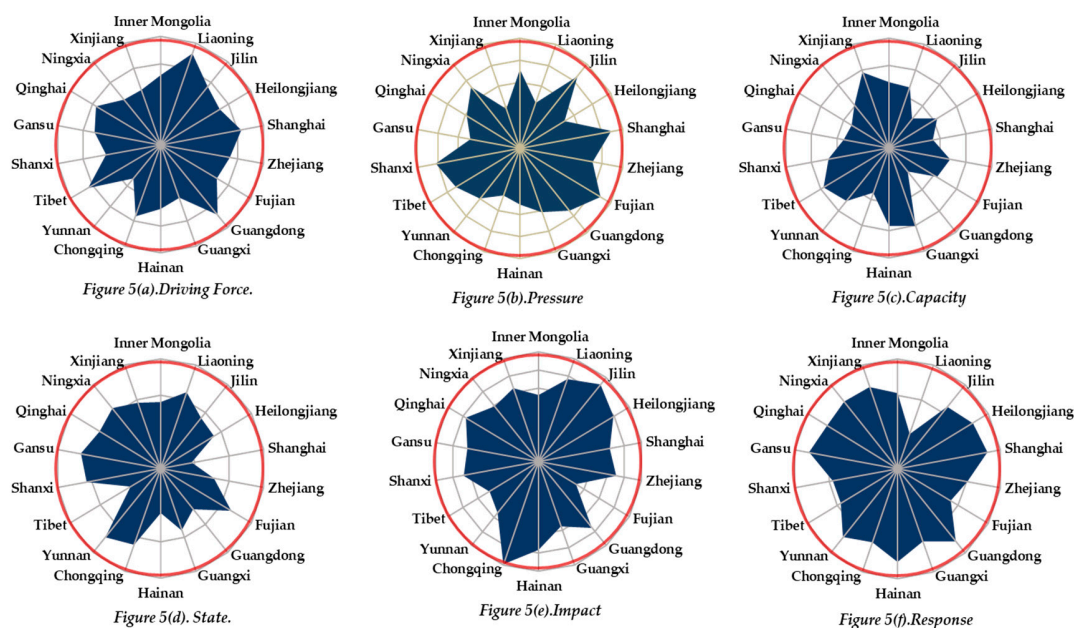
Figure 5(a).Driving Force.

Figure 5(b).Pressure

Figure 5(c).Capacity

Figure 5(d). State.

Figure 5(e).Impact

Figure 5(f).Response

Figure 4. The influence coefficient of the DPCSIR framework on water security in the One Belt And One Road Region of China from 2011 to 2016.

The evaluation values for Driving Forces, Carrying Capacity, State, and Responses in the B&R of China region show a fluctuating trend from 2011 to 2016 (see Figure 5, Figure 6, and Appendix A Table A4). The assessment values of Pressures and Impacts subsystems depict an upward trend during this period. The value of each subsystem shows an upward trend and reflects the following three main points: (1) China has paid more attention to sustainable water resource management in recent years. (2) The various investments in water resources' protection made by the Chinese provincial government have yielded encouraging results. For example, with the support of government subsidies, progressive drip irrigation technology for agricultural water use is continuously improving the efficiency of water use. (3) The government is increasingly aware that water insecurity is a risk that limits sustainable economic development. Therefore, within the time period from 2011 to 2016, China's government successively issued stringent policies for sustainable water resource management. Ecological civilization construction and river (lake) chiefs are typical examples of these series of strict water resources protection policies put in place during this time period. These policies contribute to the improvement of water security. However, there is still room for improvement.

In the Driving Forces subsystem, the indicators of per capita income, the urbanization rate, and the green coverage rate show a rising trend, while Engel's coefficient shows a decreasing pattern. These increase the subsystem's value. Due to the slowing growth rate of GDP, the value of the Driving Forces subsystem shows a fluctuating trend.

By observing the assessment values of Carrying Capacity and State, it's not difficult to see that the continuous increase in population and fluctuation of annual precipitation aggravate the problem of water insecurity. The increase of per capita water use and the decrease of per capita land use result in the fluctuation in these two subsystems' assessment values. This confirms the fact that environmental protection should be balanced with socio-economic development [77,78]. That's why the weights of Carrying Capacity and State subsystem are greater in the water resource security assessment index (See Appendix A Table A1).

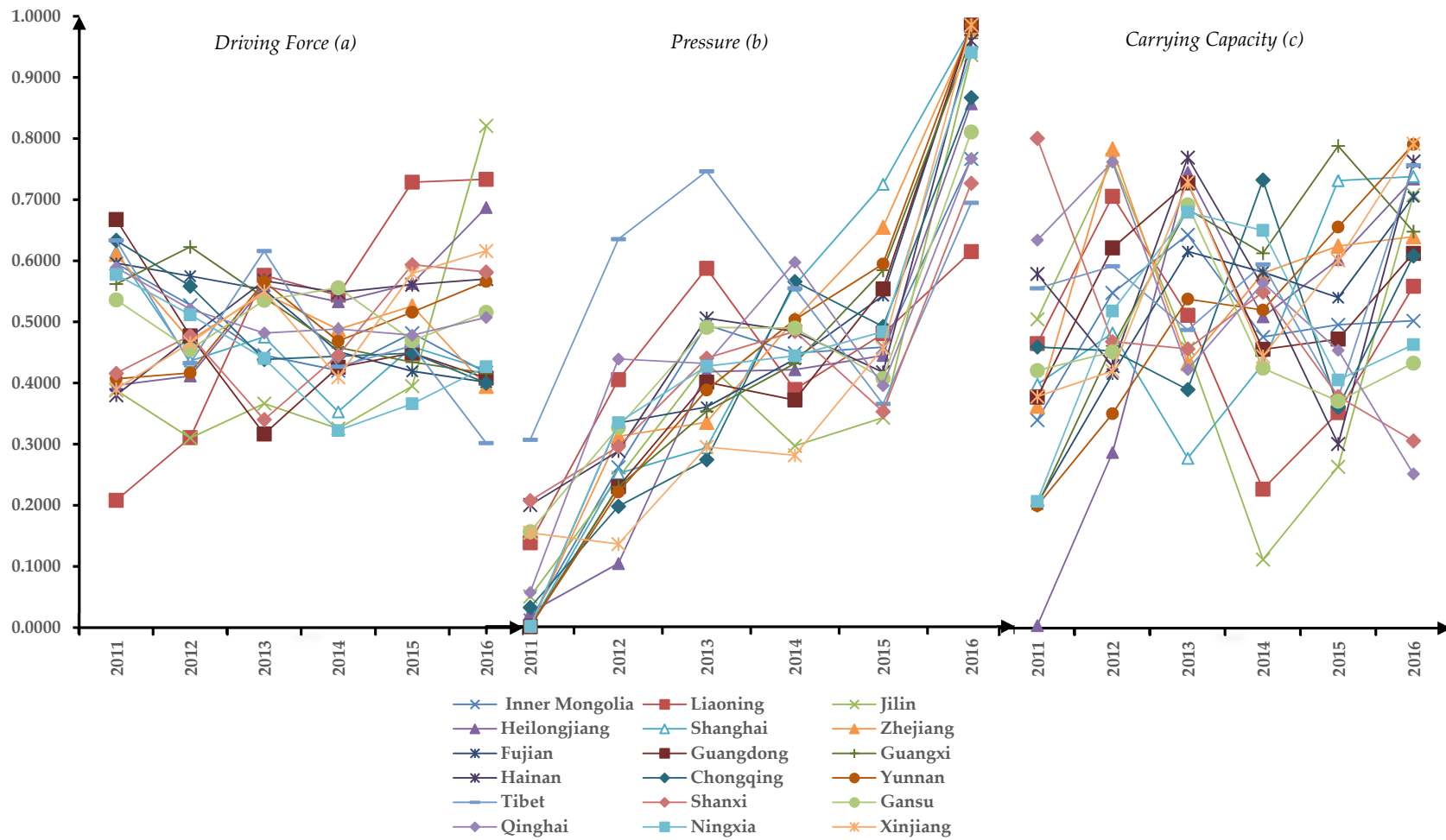**Figure 5.** Driving Force (**a**), Pressure (**b**), and Carrying Capacity (**c**) subsystems in the One Belt and One Road Area of China.
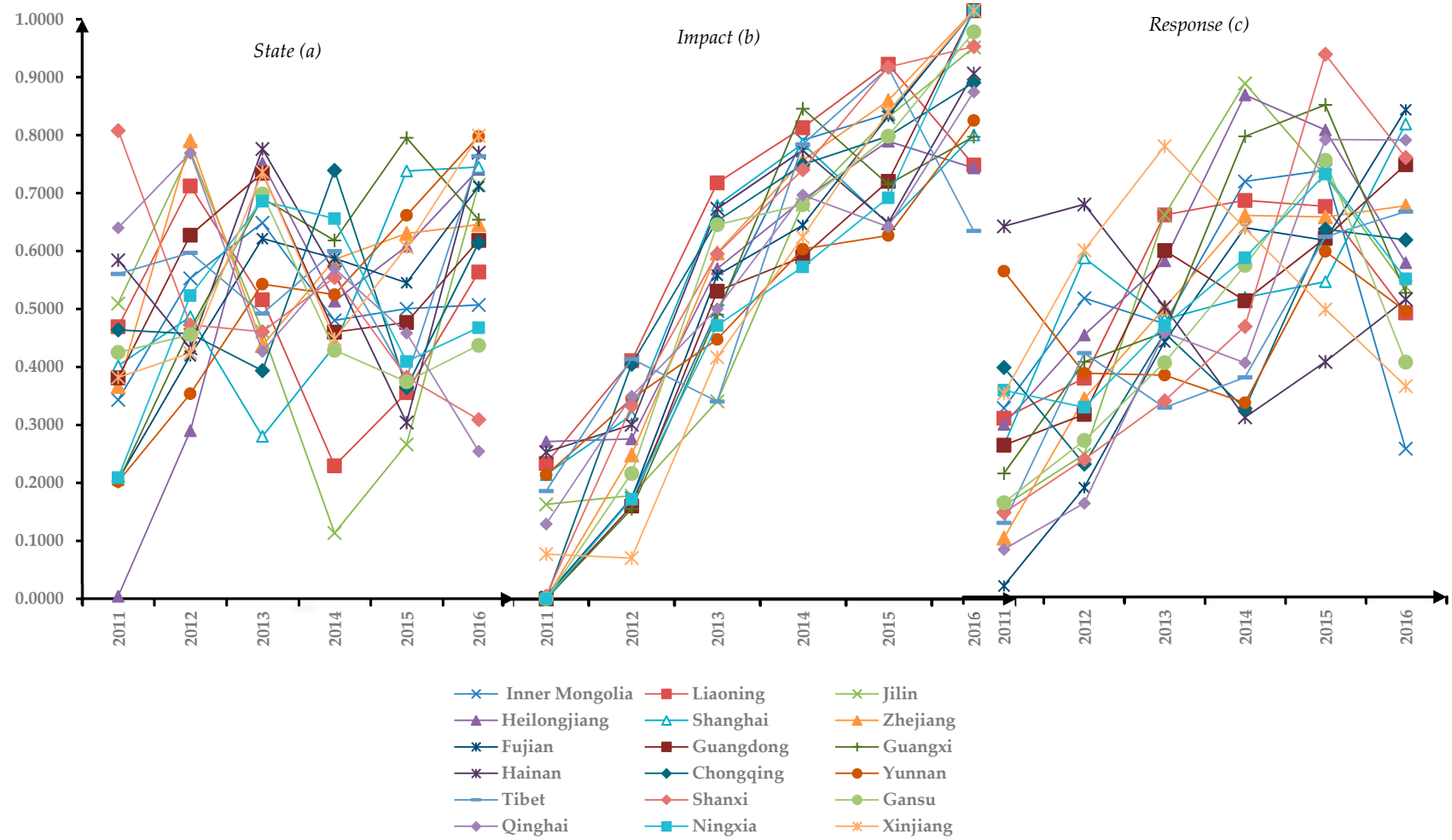
Figure 6. State (**a**), Impact (**b**), and Response (**c**) subsystems in the One Belt and One Road Area of China.

The Pressures and Responses subsystems achieved relatively high values in the assessment framework due to the increase of government inputs, such as the reduction of waste-water discharge, the increase of water consumption efficiency and the increase of sewage treatment efficiency.

Further, it is worth noting that the high efficiency of water resources development and utilization limited the growth of the assessment values of Pressures subsystem. In order to improve its value, environmental protection expenditure and improvement and popularization of efficient water resources utilization technologies need to be researched. At the same time, environmental protection expenditures and investments in science and technology need to be increased in order to support the upgrading and promotion of water resources utilization technologies. Vulnerable areas are more exposed and less capable of adapting to various stress factors due to limited infrastructure and inputs [79]. As a result, acceptable investment in environmental protection and science and technology are much needed to enhance water availability and protect these areas from the negative consequences of water insecurity.

For the SSPG area, the values of Driving Forces and State are slightly higher than the One Road and One Belt regions. This is because the provincial governments in this region have better water resources use and protection systems as well as faster economic growth. In areas where the population number is small, the geographical location is relatively closed, and the economic status is comparatively weaker, water pollution and use inefficiency are not significant. These factors have positive effects on the value of Carrying Capacity and State subsystems, but negative effects on the value of Response and Pressure subsystems. That means the government prioritizes economic development in these regions. For this reason, investment in environmental protection is minimal. Hence, provinces like Tibet, Chongqing, and Yunnan require more investment in ecological and water resources protection initiatives to boost the values of the State and Pressures subsystems. At the same time, they need to take advantage of the B&R initiative to seek industrial cooperation with foreign countries, upgrade domestic industries, and realize positive interactions between economic development and water resources protection.

The assessment of Pressures, Impacts, and Carrying Capacity subsystems show higher values for One Road region than the SSPG and One Belt areas. This might be due to better water resources endowment, advanced water resources utilization technology, and better economic development. Many previous studies have stated that social and economic systems were the most influential factors in the water resource system [80,81]. Therefore, it is necessary to balance the investment in water resources management with the urbanization rate.

Compared to the other two regions, the One Belt area achieved a higher assessment value for the Responses subsystem. Although most provinces in the One Belt region have poor water resource endowment, relatively dry climate and undeveloped economies, they are willing to adopt active policies to solve water security problems. Therefore, their Responses subsystem evaluation value is relatively high. However, the values of State and Carrying Capacity subsystems for the One Belt region is relatively lower. The region needs to take measures to complement its weak spots. Provinces like Ningxia, Xinjiang, and Shanxi, which have lower scores for the subsystem of State, need to use various means to conduct water trading while actively improving water resource utilization efficiency. Except for Heilongjiang, which has strong Carrying Capacity, other provinces' assessment values are relatively low. Gansu, Ningxia, Liaoning, and Inner Mongolia occupy the last four positions on the rank. Hence, strengthening ecological governance, conserving water sources, and implementing a water trading market are the main courses of action that need to be strengthened in those five provinces.

3.4. Water Security Prediction for the One Belt and One Road Region in China

Using the data for the factors listed in the water security assessment index for the time period from 2011 to 2016, the Grey Model is used to predict the water security level of the B&R region for the next six years. In order to verify the accuracy of the prediction results, we test its stability by

calculating the average relative error, variance ratio, and small error probability of each province and municipality (See Table 5). According to the result, the simulation results are reliable and acceptable.

Table 5. Average relative error, variance ratio, and small error probability of the Grey Prediction Model.

Provinces & MuniciPalities	Inner Mongolia	Liaoning	Jilin	Heilongjiang	Shanxi	Gansu	Qinghai	Ningxia	Xinjiang
Relative Error	0.0369 **	0.0694 *	0.0804 *	0.0660 *	0.0325 **	0.0501 *	0.0431 **	0.0435 **	0.0921 *
Variance ratio	0.0356 ***	0.0759 ***	0.0776 ***	0.0735 ***	0.0343 ***	0.0588 ***	0.0411 ***	0.0458 ***	0.0969 ***
Small error probability	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***

Provinces & Municipalities	Shanghai	Zhejiang	Fujian	Guangdong	Hainan	Guangxi	Chongqing	Yunnan	Tibet
Relative Error	0.0352 **	0.0199 **	0.0528 *	0.1164 *	0.0881 *	0.0512 *	0.0387 **	0.0231 **	0.0278 **
Variance ratio	0.0340 ***	0.0221 ***	0.0559 ***	0.1283 ***	0.0913 ***	0.0547 ***	0.0444 ***	0.0267 ***	0.0282 ***
Small error probability	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***	1 ***

Note: ***, **, and *denote the grades good, qualified, and inadequate.

The Grey Prediction results show that the water security of the B&R area will keep rising steadily from 2017 to 2022 (See Table 6). The average water security index value in 2022 will be 1.3269, nearly double the value in 2017, which is 0.7318. This shows that as long as the relationship between socioeconomic development and environmental protection is well balanced, water security will continue to improve. It is also worth noting that the prediction of results is based on data from 2011–2016. With China's economic growth slowing down in the future and with an increasing population, the availability of water will be limited. Thus, the B&R initiative might meet more water-related challenges and the predictions might be overestimated. The One Belt area and the SSPG area need further restructuring of the industrial sector in order to save water and promote water trading. For the One Road area, the popularization of water-saving and sewage treatment technologies (e.g., closed-loop cycles in industrial processes and efficient removal of pharmaceuticals from wastewater) are needed in the future [82].

Table 6. Water security values in the B&R area of China from 2017–2022.

Regional Division	Provinces and Municipalities	2017	2018	2019	2020	2021	2022
One Belt Area	Inner Mongolia	0.6740	0.7286	0.7876	0.8514	0.9204	0.9950
	Liaoning	0.6711	0.7113	0.7539	0.7991	0.8469	0.8977
	Jilin	0.8239	0.9729	1.1489	1.3567	1.6021	1.8919
	Heilongjiang	0.7788	0.8821	0.9992	1.1319	1.2821	1.4523
	Shanxi	0.7406	0.8424	0.9583	1.0901	1.2401	1.4107
	Gansu	0.7053	0.7784	0.8590	0.9480	1.0462	1.1546
	Qinghai	0.6911	0.7612	0.8385	0.9236	1.0173	1.1205
	Ningxia	0.6312	0.7667	0.8450	0.9313	1.0264	1.1312
	Xinjiang	0.7241	0.8117	0.9100	1.0201	1.1436	1.2820
One Road Area	Shanghai	0.8383	0.9823	1.1511	1.3489	1.5806	1.8522
	Zhejiang	0.7806	0.8839	1.0008	1.1332	1.2831	1.4528
	Fujian	0.8101	0.9383	1.0869	1.2590	1.4583	1.6892
	Guangdong	0.6939	0.8412	0.9584	1.0918	1.2438	1.4170
	Hainan	0.7384	0.7563	0.8244	0.8986	0.9794	1.0675
SSPG Area	Guangxi	0.7527	0.8352	0.9267	1.0283	1.1409	1.2660
	Chongqing	0.6867	0.7641	0.8502	0.9460	1.0526	1.1712
	Yunnan	0.8096	0.9506	1.1163	1.3108	1.5392	1.8074
	Tibet	0.6224	0.6585	0.6967	0.7371	0.7799	0.8251

4. Conclusions and Recommendations

From the assessment of water security in provinces and municipalities of the B&R in China for the time period from 2011 to 2016, the following conclusions are drawn: (1) Water security level is dynamic. It is highly influenced by the subsystem of Responses, State, Pressures, and Carrying Capacity. (2) The

spatial water security variation within the study area depicts the following trend: the One Road area is doing slightly better than the other two regions. While the water security improvement rate depicts the following pattern: the One Belt area is better than the Strategy Support and Pivotal Gateway of the B&R area (SSPG area), and the SSPG area is better than the One Road area. (3) From the perspective of each subsystem, the evaluation values for Driving Forces, Carrying Capacity, State, and Responses in the B&R of China region show a fluctuating trend from 2011 to 2016. The assessment values of the Pressures and Impacts subsystems depict an upward trend during this period. (4) The results from the Grey Model show that the water security of the B&R region in China will portray a rising trend from 2017 to 2022.

The One Belt and One Road Initiative is both an opportunity and a challenge to the water resources protection and socio-economic development of all the provinces and municipalities in China. There is no doubt that the B&R initiative's opportunities outweigh its challenges. Compared with the traditional water resources management, a wide area management scheme like the B&R initiative has broad advantages and addresses more challenges.

The subsystems of State, Pressures, Carrying Capacity, and Responses are the most important factors which have great influence on water security. The government cannot entirely solve the water security problems only by working on the subsystem of Responses. The government needs to innovate water resource management mechanisms and design stricter enforcing measures for efficient use and allocation of water.

Therefore, it's better to consider the following aspects. Firstly, the central government needs to introduce more incentive policies to promote cross-regional and provincial water trading cases, leading to the improvement of water resources utilization rate and optimal allocation of water resources. Secondly, the policymakers need to carry out stricter water pollution control measures, and control the discharge of waste-water and improve the sewage treatment rate. Thirdly, the provincial government needs to consider appropriately increasing investment of infrastructure construction and innovative water-saving technology, and perfect the relevant new and existing laws and regulations so as to ensure the sustainable utilization of water resources. Lastly, all regions need to formulate mutually complementary water consumption strategic plans according to the water resource endowment of each region in order to balance socio-economic development and ecological conservation. These measures will fundamentally improve the water security level of China's B&R region.

In summary, the main contributions of this paper are the following: First of all, it presents a water security assessment index system using the Driving Forces-Pressures-Carrying Capacity-State-Impacts-Responses model. Then, it identifies the limitations of methodological approaches used for water security assessment and the evolution of the DPCSIR model. Finally, it puts forward specific suggestions for water resource management policies in the B&R region of China, which might be beneficial to improve the water security status of this region.

Author Contributions: Z.Z. and M.A. proposed the research ideas and methods. W.H., J.S., D.M.D., Z.L. and L.Y. revised the paper. M.A. and X.W. were responsible for data collection and creating the figures.

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

Abbreviations

The following abbreviations are used in this manuscript:

DPCSIR	Driving Forces-Pressures-Carrying Capacity-State-Impacts-Responses
B&R	One Belt and One Road Initiative
SSPG	The Strategy Support and Pivotal Gateway of One Belt and One Road Initiative

Appendix A

Table A1. The impact coefficient of DPCSIR subsystems on water security in the One Belt and One Road region of China from 2011 to 2016.

Regional Division	Provinces and Municipalities	D	P	C	S	I	R
One Belt Area	Inner Mongolia	0.1630	0.1692	0.1669	0.1690	0.1316	0.2003
	Liaoning	0.1680	0.1664	0.1667	0.1710	0.1328	0.1951
	Jilin	0.1640	0.1706	0.1619	0.1690	0.1335	0.2010
	Heilongjiang	0.1632	0.1669	0.1657	0.1688	0.1330	0.2024
	Shanxi	0.1606	0.1702	0.1666	0.1707	0.1324	0.1994
	Gansu	0.1628	0.1668	0.1637	0.1716	0.1322	0.2030
	Qinghai	0.1642	0.1678	0.1632	0.1701	0.1328	0.2018
	Ningxia	0.1608	0.1693	0.1653	0.1707	0.1320	0.2019
	Xinjiang	0.1608	0.1658	0.1697	0.1695	0.1323	0.2019
One Road Area	Shanghai	0.1658	0.1709	0.1636	0.1645	0.1322	0.2031
	Zhejiang	0.1635	0.1691	0.1670	0.1678	0.1325	0.2001
	Fujian	0.1625	0.1709	0.1657	0.1717	0.1305	0.1988
	Guangdong	0.1669	0.1694	0.1607	0.1673	0.1327	0.2030
	Hainan	0.1619	0.1671	0.1692	0.1661	0.1328	0.2028
SSPG Area	Guangxi	0.1605	0.1682	0.1701	0.1690	0.1318	0.2005
	Chongqing	0.1641	0.1665	0.1637	0.1711	0.1340	0.2007
	Yunnan	0.1582	0.1680	0.1676	0.1723	0.1317	0.2022
	Tibet	0.1660	0.1690	0.1694	0.1650	0.1313	0.1994
Average Value		0.1632	0.1684	0.1659	0.1692	0.1692	0.2010

Note: SSPG area is short for the strategy support and pivotal gateway of B&R areas.

Table A2. The marginal growth rate of the One Belt and One Road region in China from 2012 to 2016.

Regional Division	Provinces and Municipalities	2012	2013	2014	2015	2016
One Belt Area	Inner Mongolia	0.7049	0.1987	0.0708	0.0718	0.0275
	Liaoning	0.6848	0.3313	−0.1343	0.1720	0.0059
	Jilin	0.5577	0.1953	−0.0065	0.1841	0.3848
	Heilongjiang	0.8490	0.5160	0.0009	0.1103	0.1257
	Shanxi	0.0359	0.1496	0.1946	0.1609	0.0464
	Gansu	0.2510	0.3790	−0.0071	0.0842	0.1063
	Qinghai	0.4827	0.0007	0.2140	0.0034	0.1889
	Ningxia	0.3594	0.3020	0.0412	0.0537	0.1203
	Xinjiang	0.1089	0.4850	−0.1704	0.2071	0.2049
One Road Area	Shanghai	0.1396	0.0202	0.2940	0.1685	0.1523
	Zhejiang	0.4692	0.0922	0.2136	0.1125	0.0995
	Fujian	0.8840	0.3338	0.0715	0.0604	0.2954
	Guangdong	0.1765	0.3919	−0.1008	0.1138	0.3437
	Hainan	0.0691	0.2771	−0.1226	−0.0654	0.5367
SSPG Area	Guangxi	0.5612	0.2061	0.1881	0.0842	0.0030
	Chongqing	0.1295	0.1652	0.1843	−0.0273	0.1995
	Yunnan	0.1329	0.2449	0.0659	0.2283	0.1877
	Tibet	0.3292	0.0052	0.0509	0.0446	0.1317

Table A3. The key indicators affecting the marginal growth rate of four provinces.

	Liaoning	Guangdong	Hainan	Xinjiang
Responses	R1; R2; R6	R3; R4	R3; R4	R3; R4
State	S2; S3	S1; S3; S4	S1; S3; S4	S1; S3; S4
Pressures	P3; P2	P3; P5	P3; P5	P3; P5
Carrying Capacity	C3; C5; C2	C1; C3; C5	C1; C3; C5	C1; C3; C5
Driving Forces	D1; D3; D5	D3; D4	D3; D4; D5	D3; D4; D5
Impacts	——	I3; I4	I3; I4	——

Note: Saving water consumption is short for R1; Urban sewage treatment rate is for R2; Treatment capacity of urban sewage treatment plants is short for R3; Length of water supply pipe is short for R4; The proportion of science and Technology expenditure is Short for R6; Daily water supply capacity is short for S1; Daily water consumption per capita is short for S2; Agricultural water consumption is short for S3; Industrial water consumption is short for S4; Utilization rate of water resource development is short for P2; Discharge of industrial waste-water from ten thousand Yuan output value is short for P3; Ammonia Nitrogen discharge is short for P5; Effective irrigation area is short for C1; Per capita cultivated land area is short for C2; Per capita water resources is short for C3; Annual precipitation is short for C5; GDP growth rate is short for D1; Population density is short for D2; Per capita net income (Yuan) of urban residents is short for D3; Engel coefficient is short for D4; Population growth rate is short for D5; Proportion of added value of Tertiary industry is short for I3; Green coverage rate of built-up Areas is short for I4.

Table A4. The evaluation values of subsystems in the One Belt and One Road region of China from 2011 to 2016.

Regional Division	Provinces and Municipalities	Driving Force Index						Mean Value	Ranking
		2011	2012	2013	2014	2015	2016		
One Belt area	Inner Mongolia	0.5954	0.5273	0.4454	0.4205	0.4816	0.4170	0.4812	12
	Liaoning	0.2080	0.3107	0.5760	0.5437	0.7286	0.7333	0.5167	3
	Jilin	0.3882	0.3102	0.3665	0.3257	0.3950	0.8208	0.4344	18
	Heilongjiang	0.3964	0.4115	0.5588	0.5329	0.5628	0.6870	0.5249	1
	Shanxi	0.4159	0.4777	0.3401	0.4456	0.5936	0.5817	0.4758	14
	Gansu	0.5361	0.4546	0.5355	0.5559	0.4694	0.5156	0.5112	4
	Qinghai	0.5890	0.5208	0.4819	0.4885	0.4783	0.5073	0.5110	5
	Ningxia	0.5776	0.5118	0.4402	0.3224	0.3661	0.4268	0.4408	17
	Xinjiang	0.3900	0.4657	0.5500	0.4094	0.5792	0.6161	0.5017	8
One Road area	Shanghai	0.6153	0.4361	0.4752	0.3530	0.4591	0.4219	0.4601	15
	Zhejiang	0.6107	0.4699	0.5468	0.4877	0.5261	0.3947	0.5060	6
	Fujian	0.5961	0.5750	0.5530	0.4512	0.4194	0.4015	0.4994	9
	Guangdong	0.6676	0.4772	0.3166	0.4259	0.4489	0.4081	0.4574	16
	Hainan	0.3801	0.4751	0.5674	0.5482	0.5610	0.5701	0.5170	2
SSPG area	Guangxi	0.5619	0.6227	0.5400	0.4580	0.4342	0.4159	0.5054	7
	Chongqing	0.6333	0.5585	0.4386	0.4438	0.4489	0.4000	0.4872	11
	Yunnan	0.4070	0.4165	0.5661	0.4686	0.5159	0.5661	0.4900	10
	Tibet	0.6335	0.4325	0.6158	0.4268	0.4610	0.3018	0.4786	13
Regional Division	Provinces and Municipalities	Pressure Index						Mean Value	Ranking
		2011	2012	2013	2014	2015	2016		
One Road area	Inner Mongolia	0.0095	0.2647	0.5015	0.4544	0.4645	0.7777	0.3697	7
	Liaoning	0.1390	0.4102	0.5954	0.3939	0.4866	0.6232	0.2943	18
	Jilin	0.0496	0.2468	0.4381	0.3002	0.3471	0.9503	0.3480	12
	Heilongjiang	0.0231	0.1044	0.4235	0.4268	0.4503	0.8691	0.3227	14
	Shanxi	0.2089	0.2991	0.4460	0.4906	0.3571	0.7369	0.4352	2
	Gansu	0.1573	0.3307	0.4972	0.4960	0.4122	0.8222	0.4048	4
	Qinghai	0.0564	0.4447	0.4370	0.6055	0.4004	0.7780	0.4242	3
	Ningxia	0.0000	0.3387	0.4326	0.4499	0.4898	0.9545	0.3644	8
	Xinjiang	0.1555	0.1369	0.2984	0.2845	0.4624	1.0000	0.3057	17
One Belt area	Shanghai	0.0000	0.2543	0.2971	0.5674	0.7351	0.9955	0.3579	10
	Zhejiang	0.0000	0.3159	0.3394	0.5103	0.6640	0.9933	0.3302	13
	Fujian	0.0000	0.3382	0.3647	0.4441	0.5499	1.0000	0.3774	6
	Guangdong	0.0000	0.2322	0.4061	0.3763	0.5613	1.0000	0.3501	11
	Hainan	0.2018	0.2917	0.5124	0.4905	0.4225	0.9738	0.3137	15
SSPG area	Guangxi	0.0000	0.2322	0.3576	0.4372	0.5923	0.9782	0.3073	16
	Chongqing	0.0313	0.1995	0.2773	0.5734	0.4987	0.8794	0.3591	9
	Yunnan	0.0000	0.2233	0.3930	0.5099	0.6027	1.0000	0.3810	5
	Tibet	0.3102	0.6439	0.7567	0.5621	0.3699	0.7043	0.4422	1

Table A4. *Cont.*

Regional Division	Provinces and Municipalities	Carrying Capacity Index						Mean Value	Ranking
		2011	2012	2013	2014	2015	2016		
One Belt area	Inner Mongolia	0.3432	0.5530	0.6487	0.4804	0.5006	0.5070	0.2818	14
	Liaoning	0.4694	0.7125	0.5160	0.2294	0.3556	0.5639	0.2708	15
	Jilin	0.5097	0.7723	0.4613	0.1134	0.2663	0.7145	0.2921	11
	Heilongjiang	0.0042	0.2898	0.7518	0.5136	0.6081	0.7408	0.3605	2
	Shanxi	0.8079	0.4726	0.4606	0.5545	0.3822	0.3091	0.2685	16
	Gansu	0.4250	0.4557	0.6983	0.4288	0.3745	0.4372	0.2389	18
	Qinghai	0.6401	0.7690	0.4268	0.5697	0.4585	0.2545	0.2864	13
	Ningxia	0.2092	0.5232	0.6860	0.6561	0.4093	0.4678	0.2656	17
	Xinjiang	0.3820	0.4241	0.7362	0.4484	0.6068	0.7992	0.3417	7
One Road area	Shanghai	0.4021	0.4869	0.2803	0.4360	0.7382	0.7449	0.3469	4
	Zhejiang	0.3662	0.7905	0.4370	0.5853	0.6302	0.6458	0.3543	3
	Fujian	0.2052	0.4192	0.6214	0.5874	0.5453	0.7115	0.2876	12
	Guangdong	0.3812	0.6274	0.7344	0.4600	0.4767	0.6183	0.3020	9
	Hainan	0.5843	0.4323	0.7762	0.5632	0.3040	0.7699	0.3912	1
SSPG area	Guangxi	0.2021	0.4657	0.6910	0.6183	0.7955	0.6542	0.3420	6
	Chongqing	0.4639	0.4573	0.3937	0.7392	0.3643	0.6143	0.2975	10
	Yunnan	0.2021	0.3537	0.5429	0.5248	0.6616	0.7979	0.3196	8
	Tibet	0.5606	0.5970	0.4919	0.5999	0.3798	0.7637	0.3456	5
Regional Division	Provinces and Municipalities	State Index						Mean Value	Ranking
		2011	2012	2013	2014	2015	2016		
One Belt area	Inner Mongolia	0.1777	0.4702	0.5249	0.4610	0.5480	0.8171	0.4998	5
	Liaoning	0.2578	0.5269	0.6070	0.5355	0.5980	0.6209	0.5243	3
	Jilin	0.2323	0.5561	0.4340	0.3950	0.7033	0.6165	0.4895	8
	Heilongjiang	0.2242	0.6620	0.4864	0.3648	0.5562	0.6064	0.4833	10
	Shanxi	0.5714	0.4693	0.4765	0.4750	0.4429	0.4905	0.4876	9
	Gansu	0.5367	0.5760	0.4732	0.4660	0.6371	0.7635	0.5754	1
	Qinghai	0.3262	0.4712	0.3822	0.5429	0.4587	0.6771	0.4764	12
	Ningxia	0.5236	0.4570	0.5732	0.6048	0.6694	0.4571	0.5475	2
	Xinjiang	0.6020	0.4335	0.4702	0.3575	0.4248	0.3645	0.4421	16
One Road area	Shanghai	0.6350	0.2872	0.3027	0.5932	0.6313	0.5104	0.4933	7
	Zhejiang	0.6222	0.3389	0.3647	0.3724	0.4311	0.4352	0.4274	17
	Fujian	0.3561	0.5508	0.5367	0.5369	0.5679	0.5845	0.5221	4
	Guangdong	0.5236	0.3832	0.4963	0.4304	0.2853	0.4180	0.4228	18
	Hainan	0.3678	0.4302	0.4348	0.4239	0.5290	0.6673	0.4755	14
SSPG area	Guangxi	0.5739	0.5501	0.4622	0.4147	0.4351	0.5424	0.4964	6
	Chongqing	0.4649	0.5222	0.5424	0.4831	0.4242	0.4194	0.4760	13
	Yunnan	0.4584	0.4373	0.3898	0.4934	0.5371	0.5827	0.4831	11
	Tibet	0.3910	0.4136	0.4078	0.4271	0.5585	0.5791	0.4628	15

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