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Factors Influencing Water Resource Levels Under the Water Resource Carrying Capacity Framework: A Dynamic Qualitative Comparative Analysis Based on Provincial Panel Data

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Abstract: Most existing evaluation frameworks for water resource carrying capacity (WRCC) neglect the interdependencies between subsystems. To fill this gap, we introduce a dynamic qualitative comparative analysis (QCA) model to evaluate WRCC and apply it to a vital economic development corridor, the Yangtze River Economic Belt (YREB). Ecological, social, and economic subsystems are defined as condition subsystems, while the water resource subsystem is defined as the outcome subsystem. The entropy weight method is used to calculate and calibrate the comprehensive score of each subsystem. By analyzing the necessity of a single condition subsystem and the sufficiency of condition subsystem configuration via a dynamic QCA, we qualitatively analyze the impact extent and pathways of the ecological, social, and economic subsystems on the water resource subsystem within the WRCC framework. The results reveal generally stable water resource levels despite regional variances, thereby pinpointing the influence pathways, including ecological–social and ecological–economic configurations. The 2011–2015 period saw poor stability, which subsequently improved until 2019 before declining in 2020 in the YREB. The middle-reach urban cluster showed the highest stability, which was less impacted by condition subsystems. These findings could enable provinces and municipalities to tailor policies and enhance subsystem levels for better water resource management.

Keywords: water resource carrying capacity; subsystem interaction; dynamic qualitative comparative analysis; Yangtze River Economic Belt

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1. Introduction

Water resources are among the most precious and critical natural assets on earth, playing crucial roles in the ecological cycle [1], human society development, and ecological environment protection [2–5]. Yet, globalization and industrialization have led to water scarcity, pollution, and freshwater ecosystem degradation in many countries and regions [6]. In particular, rapid population growth and expansive economic development in developing countries have brought higher water resource demands [7,8]. Meanwhile, climate change and global warming have notably affected the distribution, availability, and quality of water resources [9]. Due to close interactions between human society and the natural environment, water resource issues have become increasingly prominent. Water resources in numerous regions cannot meet the demands of the local population and economic growth [10], posing a severe challenge to human survival and development. To balance water supply and consumption, studying the supply–demand relationship of water resources, i.e., water resource carrying capacity (WRCC), is of great significance for the sustainable utilization of water resources within a region [11,12].

WRCC originates from the broader resource and environment carrying capacity concept and is a subdivision pertaining specifically to water resources based on their constitutive elements [12]. Current academic discussions mainly have two interpretations of WRCC: the scale of water resource development [13] and water resources' support capacity for sustainable development [14]. The first perspective is based on assessing the total water resources and discussing the water supply capacity limit for industrial, agricultural, and domestic demands, considering the supply–demand balance and the potential for future development as WRCC indicators [15]. The second perspective focuses on how water resources can fully support population growth and socio-economic progress, indicating the ability of a region's water resources to match its population and economic scale [15]. The former emphasizes conceptualizing WRCC with a quantitative indicator, while the latter takes social and economic factors as the core basis for carrying capacity assessment, thereby mapping the WRCC in a given locality [15].

Most existing studies quantify WRCC with various evaluation indicator systems, involving establishing a set of evaluation indicators and employing mathematical models for WRCC analysis and quantification [16]. Such evaluation indicator systems are typically based on scientific, systematic, dynamic, and measurability principles and reflect the coordination between humans and water. These evaluation systems are structured according to the goal layer–criteria layer–element layer–indicator layer framework [17,18]. WRCC is regarded as the ultimate goal. The social and economic frameworks are the foundations, and relevant reference indicators are selected from multi-level rules within ecosystems and water resource systems to build the comprehensive evaluation indicator system for WRCC [19,20]. This system comprehensively assesses the usage and management of water resources, ensuring it can support the current and future socio-economic needs while preserving and maintaining ecological environment sustainability. The existing WRCC calculation methods, listed in Table S1, contribute significantly to regional water resource assessment, planning, and sustainable development.

However, existing research on WRCC has mainly focused on developing new quantification methods or utilizing system dynamics to simulate water usage scenarios and determine maximum populations and water resource management schemes [21]. The influences and interactions among subsystems within the WRCC framework are rarely explored. Wang and his team employed the panel vector autoregression (PVAR) model to evaluate WRCC, exploring its internal dynamics from the perspectives of water resources, economy, society, and ecological environment [15]. As a panel data model based on the vector autoregression (VAR) model, PVAR models and estimates relationships among multiple panel data variables. By estimating the correlations and dynamic relationships between multiple panel data variables based on estimated model parameters, the PVAR model reveals the relationship characteristics. Additionally, it can capture the dynamic relationships between variables using lagged terms and thus predict changes in the variables, making it suitable for WRCC evaluation [15]. Wang and his team took the perspectives of water resources, society, economy, and ecological environment and used the coupling coordination degree model and the PVAR model to explore the internal dynamic interactions of the WRCC system [15]. They also used the geographically and temporally weighted regression (GTWR) model to determine the drivers for WRCC evolution, thereby improving the WRCC of 21 cities in Guangdong. However, the existing research exploring the interactions among subsystems within the WRCC framework has neglected the interdependencies among the subsystems, failing to explore the influences of multiple condition subsystems on the outcome subsystem.

Qualitative comparative analysis (QCA) was initially formulated by the American social scientist Charles C. Ragin to reconcile case studies with dataset analyses due to its suitability for medium-N research designs [22]. While medium-N does not require a large number of cases like statistical research, it goes beyond the qualitative case studies of single or small samples. The key idea of QCA is to emphasize configurations to study the interactive effects of various conditions on the outcome rather than the impact of a single condition [22]. Researchers can use binary, categorical, or raw data in the process. QCA has been widely applied in social sciences, including political science, sociology, organizational studies, economics, and education. With the continuous advancement in research methodology, QCA has been applied to public policy [23], management studies [24,25], and educational research [26,27]. For instance, public policy analysts can perform a QCA to decipher which policy combinations can effectively achieve the desired outcomes. In organizational behavior research, QCA helps analyze the impact of different organizational structures and management strategies on organizational performance. Overall, QCA has facilitated a better understanding of social phenomena, broadened research methods and perspectives, and bridged the gap between quantitative and qualitative research, thereby offering significant theoretical and practical value. However, traditional QCA, constrained by theory and tools, has mostly been limited to cross-sectional data and struggles to explore the temporal dynamics of configurations [28]. The changes in WRCC and the interactions among subsystems within the WRCC framework are continuous events occurring over a temporal axis. A solitary cross-sectional configuration is insufficient to elucidate the causality–time interplay.

The goal of this study was to incorporate dynamic QCA for WRCC assessment. Taking the impacts of ecological, social, and economic subsystems on the water resource subsystem as an example, this study explores the combined and synergistic effects of the condition subsystems on the outcome subsystem. We use a vital economic development corridor, the Yangtze River Economic Belt, as a study area to examine the assessment framework. Accordingly, an evaluation system is first established comprising water resources, ecological environment, society, and the economy as subsystems, thereby concretizing the system participants and clarifying their interactions. Subsequently, the comprehensive scores of each subsystem across different provinces and years are calculated. The results are then calibrated, and the necessity of individual condition subsystems and the sufficiency of condition subsystem configurations are analyzed.

2. Methodology

This study employed a dynamic QCA and drew on relevant theories and methods proposed by Roberto García-Castro and Miguel A. Ariño [29]. Obstacles between the panel data and QCA were transcended using the R programming language to explore the configuration relationships under the influence of temporal effects. The experimental procedures are as follows. First, a WRCC evaluation system is established based on subsystem layers, i.e., the water resource, ecological environment, social, and economic subsystems. The water resource subsystem is designated as the outcome subsystem, and the ecological environment, social, and economic subsystems as condition subsystems. Then, the weight of each subsystem is determined using the entropy weight method. Upon determining weights for each subsystem, the annual composite scores are computed for each subsystem in the provinces and municipalities. Finally, a dynamic QCA is conducted on the Yangtze River Economic Belt's water resources, ecological environment, society, and economy. First, we calibrate the annual comprehensive scores of each subsystem at both the provincial and municipal levels. Based on the calibration results, we analyze the necessity of individual conditional subsystems to determine whether high or low water resource subsystems require robust or fragile ecological, social, and economic subsystems. This step investigates the influence extent and modes of individual condition subsystems on the outcome subsystem. Subsequently, the calibrated results are used to build a truth table, which is minimized logically to obtain an intermediate solution and extract a simple one. Based on the intermediate and simple solutions, tables are constructed to facilitate the identification of key subsystems of core and peripheral conditions responsible for high water-resource levels. In this way, the influence pathways and magnitudes of the ecological, social, and economic subsystems on the water-resource subsystem can be determined. In this context, the outcome subsystem is influenced by the condition subsystems and is the primary measurement or observation target, and the condition subsystems impact the outcome subsystem. The process flowchart is presented in Figure 1.

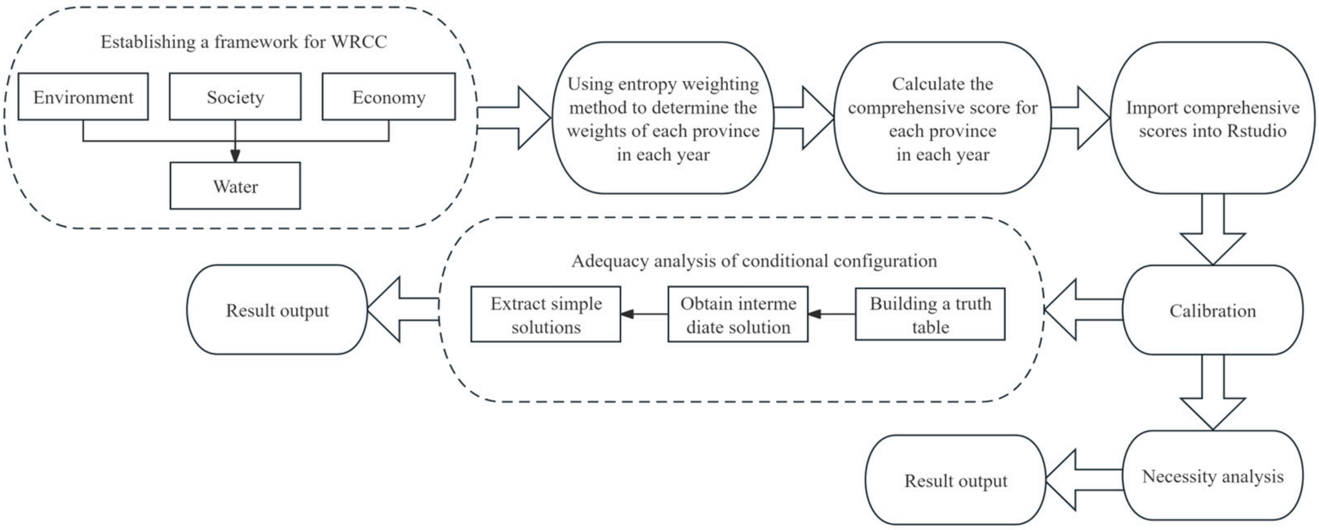

Figure 1. Process diagram for dynamic QCA research on the WRCC framework in the Yangtze River Economic Belt.

2.1. Comprehensive Score of WRCC Subsystem

2.1.1. WRCC Evaluation System Establishment

To visualize the relationships among participants within the WRCC system, research subjects are selected from four perspectives: water resources, ecological environment, economy, and society. Drawing on existing research [30,31], expert opinions, and the status of data collection, a comprehensive WRCC evaluation framework is constructed, encompassing the water resource, ecological environment, economic, and social subsystems (Table S2). Within this framework, the water resource subsystem is defined as the outcome subsystem, while the ecological environment, social, and economic subsystems are categorized as condition subsystems.

2.1.2. Indicator Standardization

Based on their impacts on the water resource subsystem, the indicators are categorized into positive and negative ones. Positive indicators are those with scoring trends aligning with that of the water resource subsystem, while the scoring trends of negative indicators are opposite to that of the water resource subsystem.

The range method is used to normalize the original data (Supplement S2), eliminating the impacts of positive and negative indicators on the results. The normalized data are then right shifted by 0.0001 [28]. The specific steps are as follows:

For positive indicators,

$$y_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} + 0.0001 \quad (1)$$

For negative indicators,

$$y_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} + 0.0001 \quad (2)$$

where i (i = 1, 2..., 110) represents the case number, j (j = 1, 2..., 16) represents the indicator element number, x_{ij} represents the original data, y_{ij} represents the data after nondimensionalization, and $\min(x_{ij})$ represents the minimum of the original data.

2.1.3. Weight Determination

The entropy weight method is used to determine the objective weights of the indicators [32]. The entropy weight of an indicator depends on the data dispersion degree. With greater dispersion, the data contains more information, and the weight is higher. Conversely, the weight is lower with less dispersed data. Based on the nondimensionalized data, the weights of the indicators are determined with the following steps [32]:

Calculating the proportion of the j-th indicator element for the i-th case p_{ij},

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \tag{3}$$

Calculating the entropy of the j-th indicator element for the i-th case E_{ij},

$$E_{ij} = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{4}$$

where n = 110 is the total number of cases.

The variation coefficient of the j-th indicator element G_j is calculated as follows:

$$G_j = 1 - E_j \tag{5}$$

The weight of the j-th indicator element ω_j is calculated as follows:

$$\omega_j = \frac{G_j}{\sum_{j=1}^{m} G_j} \tag{6}$$

This study consists of m = 16 elements at the indicator level.

The comprehensive weight W_k is calculated as follows.

$$W_k = \sum_{j=4k-3}^{4k} \omega_j \tag{7}$$

where k = (1, 2, 3, 4), W_1 represents the comprehensive weight of the water resource subsystem, W_2 represents the weight of the ecological environment subsystem, W_3 represents the weight of the social subsystem, and W_4 represents the weight of the economic subsystem.

2.1.4. Comprehensive Subsystem Score Determination

An overall score is introduced as an indicator reflecting the comprehensive level of each subsystem in various cases. The overall score of each subsystem in each case is calculated as follows:

$$A_{ik} = y_{ij} W_k \tag{8}$$

where A_{i1}, A_{i2}, A_{i3}, and A_{i4} represent the comprehensive scores of the water resource, ecological environment, social, and economic subsystems, respectively, in the i-th case.

2.2. Dynamic QCA Model

2.2.1. Calibration

Dynamic QCA is based on the set-theoretic causal logic. To transform data into set membership scores ranging from 0 to 1, this research uniformly calibrates the data based on existing theory and previous studies to facilitate subsequent analyses of intra-group, intergroup, and overall consistency and coverage. In line with the variable characteristics in this study, the direct calibration method is used [33], setting the 95th, 50th, and 5th percentiles as the calibration anchors, representing fully subordinate to anchor point, intersection point, and completely not affiliated with anchor points [34].

The calibration anchors $POSITION$ are located as follows:

$$POSITION = (n+1)p_r \tag{9}$$

The percentiles $PERCENTILE$ are calculated as follows:

$$PERCENTILE = X_{ej} + f(X_{(e+1)j} - X_{ej}) \tag{10}$$

where p_r (r = 1, 2, 3) represents the percentiles to be identified, and n is the total number of cases. p_1, p_2, and p_3 indicate the 95th, 50th, and 5th percentiles. X_{ej} represents the value of the e-th $POSITION$ in column j of the dataset after sorting. $X_{(e+1)j}$ represents the value at the position $e+1$ in column j after sorting. f indicates the relative position of $POSITION$ between X_{ej} and $X_{(e+1)j}$.

Calibration results for each subsystem are obtained by calculating based on percentiles. If the calibration results include a value of 0.5, the results must be exported for further processing. Otherwise, no further action is required.

2.2.2. Necessity Analysis of Individual Condition Subsystem

A necessity analysis determines whether varying intensities of each condition subsystem are necessary conditions for the outcome subsystem to exhibit different levels. The evaluation encompasses calculating the aggregated consistency, inter-group consistency across different regions for each year, intra-group consistency within each region across different years, inter-group coverage across different regions for each year, intra-group coverage within each region across different years, overall coverage, inter-group consistency adjustment distance, and intra-group consistency adjustment distance.

The aggregated consistency $POCONS$ is evaluated as follows:

$$POCONS = \frac{\sum_{a=1}^{N} \sum_{a=1}^{T} \min(X_{at}, Y_{at})}{\sum_{a=1}^{N} \sum_{t=1}^{T} X_{at}} \tag{11}$$

The inter-group consistency across different regions for each year $BECONS$ is evaluated as follows:

$$BECONS = \frac{\sum_{a=1}^{N} \min(X_{at}, Y_{at})}{\sum_{a=1}^{N} X_{it}} \tag{12}$$

The inter-group consistency based on Euclidean distance $BECONS\ distance$ is assessed as follows:

$$BECONS\ distance = \sqrt{\sum_{t=1}^{T} \left(\frac{BECONS_t}{\sum_{t=1}^{T} BECONS_t} - \frac{1}{T}\right)^2} \tag{13}$$

The adjusted distance for inter-group consistency $BECONS\ adjusted\ distance$ is calculated as follows:

$$BECONS\ adjusted\ distance = \frac{BECONS\ distance}{\sqrt{\frac{T}{T^2+3T+2}}} \tag{14}$$

The inter-group coverage across different regions for each year $Between\ Coverage$ is evaluated as follows:

$$Between\ Coverage = \frac{\sum_{a=1}^{N} \min(X_{at}, Y_{at})}{\sum_{1}^{N} Y_{at}} \tag{15}$$

The intra-group coverage in each region for different years *Within Coverage* is evaluated as follows:

$$Within\ Coverage = \frac{\sum_{a=1}^{T} \min(X_{at}, Y_{at})}{\sum_{t=1}^{T} Y_{at}} \tag{16}$$

The pooled coverage *Pooled Coverage* is evaluated as follows:

$$Pooled\ Coverage = \frac{\sum_{a=1}^{N} \sum_{t=1}^{T} \min(X_{at}, Y_{at})}{\sum_{a=1}^{N} \sum_{t=1}^{T} Y_{at}} \tag{17}$$

The intra-group consistency within each region for different years is evaluated as follows:

$$WICONS = \frac{\sum\limits_{t=1}^{T} \min(X_{at}, Y_{at})}{\sum_{t=1}^{T} X_{at}} \tag{18}$$

The intra-group consistency based on Euclidean distance *WICONS adjusted distance* is evaluated as follows:

$$WICONS\ distance\ = \sqrt{\sum_{t=1}^{T} \left(\frac{WICONS_a}{\sum_{t=1}^{T} X_{at}} - \frac{1}{N} \right)^2} \tag{19}$$

The adjusted distance for intra-group consistency *WICONS adjusted distance* is calculated as follows:

$$WICONS\ adjusted\ distance = \frac{WICONS\ distance}{\sqrt{\frac{N}{N^2+3N+2}}} \tag{20}$$

In the above equations, a = (1, 2. . ., 11) represents different provinces and municipalities, while t = (1, 2. . .,10) indicates different years. N is the total number of provinces and municipalities. T denotes the total number of years. X_{at} signifies the membership degree of the condition subsystems in various provinces and municipalities across different years, including ecological environment, social, and economic subsystems. Y_{at} represents the membership degree of the outcome subsystems of different provinces and municipalities in the t-th year, including the water resource subsystem. $\min(X_{at}, Y_{at})$ refers to taking the minimum value between X_{at} and Y_{at}.

Using the above calculation method, further calculate the calibration results, including overall consistency, inter-group consistency of different regions for each year, intra-group consistency within each region for different years, inter-group coverage of different regions for each year, intra-group coverage within each region for different years, overall coverage, the Euclidean distance for inter-group consistency, and the Euclidean distance for intra-group consistency. Subsequently, calculations are performed to transform the intra-group Euclidean distance to an adjusted distance for intra-group consistency and the inter-group Euclidean distance to an adjusted distance for inter-group consistency.

The judgment criterion for the necessary condition analysis is as follows. If the consistency is above 0.9, the condition subsystem can be considered a potentially necessary condition for the outcome subsystem, which requires further examination. This is the case only if the coverage is above 0.5 [35], one-third of the points in the scatter plot are above the diagonal line [35,36], and the points are not concentrated on the right side of the scatter plot. If the consistency is below 0.9, the condition subsystem might not be a necessary condition for the outcome subsystem, and the same steps must be repeated to study whether the condition subsystem is a necessary condition for the outcome subsystem. When both the intra-group adjusted distance and the inter-group adjusted distance in QCA panel data analysis are below 0.1, the overall consistency precision is considered high. This can serve as a judgment basis to determine whether the condition subsystem is a necessary condition for the outcome subsystem at a specific consistency level. However, if either the inter-group adjusted distance or the intra-group adjusted distance exceeds 0.1, it is necessary to re-examine the coverage and redraw a scatter plot.

2.2.3. Sufficiency Analysis of Condition Configurations

A sufficiency analysis of condition configurations, as the core of the QCA method, focuses on examining how different antecedent condition subsystems affect the outcome subsystem through various configurations. Its criterion is based on the consistency level of configurational sufficiency. Schneider and Wagemann proposed that the overall consistency level of configurational sufficiency should not fall below 0.75 [35]. Only when the overall consistency level is not below 0.75 does the configuration have good explanatory power for the research area. The sufficiency of condition configurations is analyzed as follows. According to the specifics of this study, the calibrated data are used first to construct a truth table. During truth table construction, a consistency cutoff of 0.8 is selected per the natural breakpoint method [37]. A frequency threshold of 1 is selected, adhering to the principle of not exceeding 1.5% of the number of cases [38]. Meanwhile, a Proportional Reduction in Inconsistency (PRI) threshold of 0.75 is selected [39]. Next, the intermediate solutions are found through logical minimization. When finding intermediate solutions, 'presence' is selected for all the directional presets when the antecedent condition subsystems affect the outcome subsystem, thereby exploring the impact of the ecological environment, social, and economic subsystems on the level of the water resource subsystem. Then, simple solutions are extracted from the intermediate solutions, which are the configurations, thus identifying the core and peripheral condition subsystems that influence the water resource subsystem. Finally, the results between groups and within groups are analyzed. With lower coverage, the corresponding cases are fewer. Hence, the influence of the configuration on the region is lower. The calculation formulas for overall consistency, overall coverage, consistency, coverage, the Euclidean distance for inter-group consistency, and the Euclidean distance for intra-group consistency are consistent with those in the necessary condition analysis of individual conditions [33].

3. Case Study Area and Data Sources

The Yangtze River Economic Belt in China is a vital economic development corridor. The region spans the Yangtze River Basin, stretching from the Tibetan Plateau in the upper reaches to the East China Sea downstream. Covering approximately 21% of China's land area, the Yangtze River Economic Belt interconnects 11 provinces and municipalities, including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan, and Guizhou (Figure 2). The Yangtze, China's largest freshwater reservoir with abundant water resources, flows through this region, with its Three Gorges Dam ranking among the world's largest hydropower stations. The economic belt encompasses a wealth of natural resources and diverse geographical environments. From the high mountain areas in the west to the plains in the east, it includes various topographical features such as plateaus, basins, mountains, hills, and plains. The region possesses ample water, mineral, forest, and land resources, providing the foundation for various economic and social activities. The Yangtze River Economic Belt is crucial for China's industrialization, attracting numerous outstanding businesses and advanced industries. Furthermore, significant progress has been made in the tertiary sector, particularly in modern services.

However, the Yangtze River Economic Belt still faces several water resource issues, including uneven distribution [40] and relatively severe scarcity [41]. Furthermore, the water quality has deteriorated due to industrial, agricultural, and domestic sewage pollution [42]. Excessive water resource exploitation and pollution have also severely damaged the ecological environment of the Yangtze River Basin, with exacerbating issues such as wetland degradation, riverbed sandification, aquatic biota population reduction, and the endangerment of rare species such as the Yangtze River dolphin [43]. Therefore, controlling water pollution, protecting water resources, and conserving ecosystem diversity and integrity have become increasingly important. The Chinese government has recently intensified its efforts to protect and restore the ecological environment of the Yangtze River, hoping to slow down and reverse the ecological degradation trend [44].

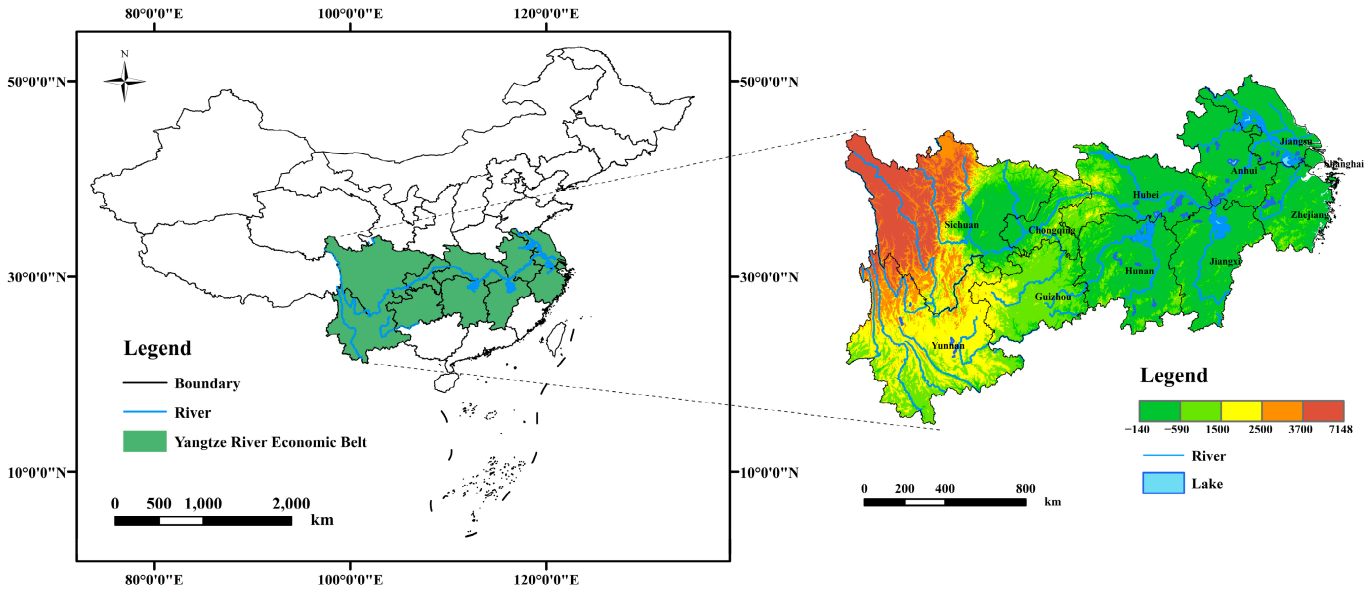

Figure 2. The geographical location of the Yangtze River Economic Belt in China.

The study area encompasses the 11 provinces and municipalities of the Yangtze River Economic Belt, and the research timeframe spans from 2011 to 2020. Economic, social, and environmental indicators were all sourced from China's environmental statistical yearbooks from 2011 to 2020. Indicators for the region's water resource, economic, social, and environmental subsystems were obtained from the provincial and municipal water resource bulletins from 2011 to 2020.

4. Results

4.1. The Necessity Analysis Results of Individual Condition Subsystem

4.1.1. Inter-Group Results of Necessity Analysis

After assigning weights to the water resource, ecological environment, social, and economic subsystems using the entropy weight method, the comprehensive scores for each province and municipality in different years are calculated. The direct calibration method is employed to find the 95th, 50th, and 5th percentiles for each subsystem. The full membership anchor, crossover point, and full non-membership anchor thus obtained are shown. Based on these values (full member anchor, intersection point, and full nonmember anchor), further calculations are performed to generate calibration results for each province and municipality in different years. Without calibration results equaling 0.5, no further export or process is needed for the calibration results.

Based on the calibration results, a necessary condition analysis was conducted on each condition subsystem, and the results are shown in Table 1. The analysis results indicate that the overall consistency levels of the ecological environment, social, and economic subsystems are below 0.9, all with either an inter-group adjusted distance, or an intra-group adjusted distance above 0.1. Therefore, they all require further examination.

First, the inter-group consistency and coverage for each case are analyzed. Cases f, h, i, j, k, and l show inter-group adjusted distances below 0.1, and the inter-group consistency is below 0.9, indicating that cases f, h, i, j, k, and l are not necessary conditions over time. The analysis then focuses on the scenarios with inter-group adjusted distances above 0.1 but inter-group consistency below 0.9 (Table 2). The findings are as follows. Firstly, cases b, c, e, and g have inter-group consistencies below 0.9 and overall coverage above 0.5, with no necessary relationship. Secondly, case a in 2018 and 2019 and case d in 2011, 2012, and 2014 show inter-group consistency above 0.9 and inter-group coverage above 0.5. Therefore, it is necessary to draw scatter plots for these two cases. With over one-third of the points above the diagonal line and not concentrated on the right side, cases a and d pass the necessity test.

Table 1. The necessity analysis results of each condition subsystem.

Condition Variable	High-Level Water Resource Subsystem				Low-Level Water Resource Subsystem			
	Consensus	**Coverage Summarization**	**Inter-Group Consistency Adjustment Distance**	**Intra-Group Consistency Adjustment Distance**	**Consensus**	**Coverage Summarization**	**Inter-Group Consistency Adjustment Distance**	**Intra-Group Consistency Adjustment Distance**
Robust ecological environment subsystem	a				b			
	0.763	0.806	0.2107	0.2598	0.483	0.51	0.2870	0.5668
Fragile ecological environment subsystem	c				d			
	0.536	0.509	0.3779	0.4745	0.816	0.775	0.1708	0.3197
Robust social subsystem	e				f			
	0.672	0.692	0.1235	0.3841	0.629	0.648	0.0618	0.5014
Fragile social subsystem	g				h			
	0.6580	0.6390	0.1453	0.3502	0.701	0.681	0.0690	0.4033
Robust economic subsystem	i				j			
	0.699	0.678	0.0981	0.3427	0.657	0.638	0.0654	0.4432
Fragile economic subsystem	k				l			
	0.627	0.646	0.0836	0.4481	0.669	0.69	0.0436	0.4832

Table 2. The condition subsystem can be considered as a potential necessary condition for the result subsystem.

Situation	**Causal Combination Situation**		**Year**									
			2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
a	Robust ecological environment subsystem and high-level water resource subsystem	Inter-group consistency	0.634	0.496	0.638	0.681	0.696	0.83	0.863	0.954	0.905	0.854
		Inter-group coverage	0.834	0.898	0.819	0.896	0.882	0.853	0.765	0.739	0.659	0.852
b	Robust ecological environment subsystem and low-level water resource subsystem	Inter-group consistency	0.297	0.3	0.396	0.454	0.468	0.608	0.592	0.617	0.611	0.598
		Inter-group coverage	0.766	0.537	0.673	0.564	0.544	0.443	0.487	0.524	0.491	0.342
c	Fragile ecological environment subsystem and high-level water resource subsystem	Inter-group consistency	0.822	0.744	0.746	0.668	0.64	0.458	0.421	0.386	0.301	0.34
		Inter-group coverage	0.374	0.518	0.482	0.565	0.567	0.623	0.527	0.478	0.412	0.596
d	Fragile ecological environment subsystem and low-level water resource subsystem	Inter-group consistency	0.936	0.943	0.894	0.916	0.898	0.798	0.714	0.693	0.575	0.741
		Inter-group coverage	0.834	0.649	0.766	0.73	0.731	0.768	0.829	0.943	0.87	0.744

Table 2. *Cont.*

Situation	Causal Combination Situation		Year									
			2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
e	Robust social subsystem and high-level water resource subsystem	Inter-group consistency	0.795	0.633	0.71	0.635	0.679	0.691	0.768	0.731	0.606	0.543
		Inter-group coverage	0.573	0.675	0.659	0.688	0.701	0.807	0.719	0.691	0.594	0.809
g	Fragile social subsystem and high-level water resource subsystem	Inter-group consistency	0.866	0.641	0.706	0.697	0.612	0.612	0.551	0.588	0.653	0.72
		Inter-group coverage	0.55	0.609	0.565	0.683	0.644	0.718	0.641	0.566	0.603	0.798

4.1.2. Intra-Group Results of Necessity Analysis

Next, the intra-group consistency and intra-group coverage of each case are analyzed. The results indicate that all cases show intra-group adjusted distances above 0.1 and intra-group consistency below 0.9 (Table 3), with the following discoveries: Cases a, b, c, d, e, f, g, h, i, j, and k have intra-group consistency above 0.2 and coverage above 0.5. Then, a scatter plot of economic subsystem membership against water resource subsystem membership is drawn, with over one-third of the points above the diagonal and not clustered on the right side. All cases pass the necessity test.

The necessary condition analysis indicates that the ecological environment, social, and economic subsystems are necessary conditions for determining the capability levels of the water resource subsystem over time. In the spatial dimension, only cases a and d pass the necessity test, meaning that a strong ecological environment subsystem is a necessary condition for the water resource subsystem in the Yangtze River Economic Belt to exhibit high capability levels in both temporal and spatial dimensions, and a fragile ecological environment subsystem is a necessary condition for the water resource subsystem to exhibit low levels.

Further, the intra-group consistency of cases b, c, e, f, g, h, i, j, k, and l are analyzed to explore whether there are regional effects in scenarios failing the necessity test. The results show that while all provinces and municipalities have cases with consistency above 0.9, Guizhou covers 9 cases (b, c, e, f, g, h, i, k, and l); Chongqing covers 8 cases (b, c, e, f, g, h, k, and l); Shanghai covers 8 cases (b, c, e, f, g, h, k, and l); Yunnan covers 4 cases (i, j, k, and l); Anhui covers 3 cases (i, k, and l); Sichuan covers 2 cases (i and j); Zhejiang covers 2 cases (h and j); Jiangxi covers 2 cases (h and j); Hubei covers 2 cases (k and l); Jiangsu covers 2 cases (I and j); and Hunan covers 1 case (h). Guizhou, Chongqing, and Shanghai having far more cases with a consistency above 0.9 suggests a significant regional effect in scenarios failing the necessity test in the spatial dimension, where the condition subsystems' impact on the outcome subsystem is clearly influenced by regional factors.

Table 3. In situations with intra-group consistency adjustment distance above 0.1 and intra-group consistency below 0.9.

Situation	Causal Combination Situation		Regions										
			Shanghai	Jiangsu	Zhejiang	Anhui	Jiangxi	Hubei	Hunan	Chongqing	Sichuan	Guizhou	Yunnan
a	Robust ecological environment subsystem and high-level water resource subsystem	Intra-group consistency	0.827	0.922	0.985	1	0.755	0.635	0.381	1	0.636	0.861	0.84
		Intra-group coverage	0.9	0.612	0.868	0.503	0.998	0.831	1	0.505	0.937	0.816	0.899
b	Robust ecological environment subsystem and low-level water resource subsystem	Intra-group consistency	0.079	0.097	1	0.593	1	0.251	0.701	0.97	0.79	0.709	0.903
		Intra-group coverage	1	1	0.193	0.957	0.116	0.737	0.4	0.761	0.531	0.789	0.389
c	Fragile ecological environment subsystem and high-level water resource subsystem	Intra-group consistency	1	1	0.085	0.915	0.331	0.799	0.772	0.527	0.681	0.777	0.428
		Intra-group coverage	0.086	0.067	1	0.412	1	0.322	0.922	0.92	0.876	0.694	0.917
d	Fragile ecological environment subsystem and low-level water resource subsystem	Intra-group consistency	0.992	0.962	0.319	0.692	0.981	0.942	1	0.369	0.906	0.835	0.764
		Intra-group coverage	0.985	0.995	0.826	1	0.26	0.853	0.26	1	0.532	0.876	0.658
e	Robust social subsystem and high-level water resource subsystem	Intra-group consistency	0.562	1	0.795	1	0.329	0.902	0.567	0.44	0.918	0.425	0.918
		Intra-group coverage	0.89	0.064	0.984	0.334	1	0.714	0.98	1	0.941	0.873	0.894
f	Robust social subsystem and low-level water resource subsystem	Intra-group consistency	0.054	0.993	1	0.898	0.983	0.515	1	0.283	1	0.415	1
		Intra-group coverage	1	0.98	0.272	0.964	0.262	0.913	0.376	1	0.468	1	0.392
g	Fragile social subsystem and high-level water resource subsystem	Intra-group consistency	1	0.688	0.412	0.892	0.757	0.89	0.639	1	0.481	1	0.376
		Intra-group coverage	0.083	0.863	1	0.732	0.998	0.45	1	0.473	1	0.593	1

Table 3. *Cont.*

Situation	Causal Combination Situation		Regions										
			Shanghai	Jiangsu	Zhejiang	Anhui	Jiangxi	Hubei	Hunan	Chongqing	Sichuan	Guizhou	Yunnan
h	Fragile social subsystem and low-level water resource subsystem	Intra-group consistency	0.994	0.051	0.941	0.379	1	0.839	0.946	1	0.874	0.947	0.73
		Intra-group coverage	0.963	1	0.502	1	0.116	0.95	0.322	0.735	0.829	0.659	0.781
i	Robust economic subsystem and high-level water resource subsystem	Intra-group consistency	0.608	1	0.639	1	0.444	0.775	0.408	0.498	1	0.92	0.964
		Intra-group coverage	0.986	0.066	1	0.366	1	0.671	1	1	0.732	0.826	0.884
j	Robust economic subsystem and low-level water resource subsystem	Intra-group consistency	0.053	0.964	1	0.822	1	0.505	0.894	0.32	1	0.871	1
		Intra-group coverage	1	0.982	0.343	0.965	0.198	0.979	0.477	1	0.334	0.917	0.369
k	Fragile economic subsystem and high-level water resource subsystem	Intra-group consistency	1	0.724	0.58	0.904	0.644	0.976	0.787	1	0.09	0.908	0.312
		Intra-group coverage	0.083	0.565	1	0.613	1	0.468	0.972	0.486	1	0.857	1
l	Fragile economic subsystem and low-level water resource subsystem	Intra-group consistency	0.999	0.082	1	0.46	1	0.83	1	1	0.198	0.835	0.685
		Intra-group coverage	0.967	1	0.378	1	0.136	0.892	0.269	0.756	1	0.925	0.885

4.2. The Sufficiency Analysis Results of Conditin Configurations

4.2.1. Summary of Results of Sufficiency Analysis

We constructed a truth table based on calibration data (Table 4). Based on the truth table, logical minimization was conducted to obtain intermediate solutions, from which simple solutions are extracted to analyze inter-group and intra-group results. The model obtained includes configuration(s), the cases corresponding to each configuration, consistency, PRI, coverage, unique coverage, summarized consistency, summarized PRI, and summarized coverage, as presented in Table 5. The overall configuration analysis results include two sets of configurations: Configuration 1: ecological environment subsystem-social subsystem; Configuration 2: ecological environment subsystem-economic subsystem. From this, one model is derived: the ecological environment subsystem–social subsystem or ecological environment subsystem–economic subsystem model. The overall solution has a summarized consistency of 0.802, above 0.75. The inter-group adjusted distances of the two configurations are below 0.1, indicating that the summarized consistency has good explanatory power over time. These two configurations can be considered sufficient conditions for the emergence of a high-level water resource subsystem over time. The intra-group adjusted distances of both configurations are above 0.1, implying the poor explanatory power of summarized consistency in the spatial dimension and a significant regional effect. Based on the intermediate and simple solutions, Table 6 provides an analysis of the core and peripheral condition subsystems within the configurations affecting the water resource subsystem level, thereby identifying the influence pathways of condition subsystems on the water resource subsystem. The ecological environment and social subsystems produce a configurational effect, jointly influencing the level of the water resource subsystem. The ecological environment and social subsystems are cores, presenting a balanced state rather than a unidimensional push, driving the water resource subsystem to exhibit high levels. The ecological environment and economic subsystems also produce a configurational effect, collectively affecting the level of the water resource subsystem. In this case, the ecological environment and social subsystems are cores, presenting a balanced state that drives the water resource subsystem to high levels.

Table 4. Truth table with 1 representing true and 0 false.

Ecological Environment Subsystem	Social Subsystem	Economic Subsystem	Output	Number of Cases in Configuration	Consistency	PRI
1	0	1	1	4	0.954	0.852
1	1	0	1	2	0.943	0.848
1	1	1	1	25	0.912	0.807
0	0	1	0	4	0.902	0.671
0	1	0	0	6	0.866	0.612
1	0	0	0	24	0.859	0.673
0	1	1	0	22	0.649	0.320
0	0	0	0	23	0.641	0.319

4.2.2. Inter-Group Results of Sufficiency Analysis

As shown in Table 6, the inter-group consistency adjustment distances of the two configurations not exceeding 0.1 suggest their good explanatory power in the temporal dimension and no significant temporal effect. Further observation of the inter-group consistency of each year (Figure 3) reveals that consistency above 0.75 indicates that the configuration is a sufficient condition affecting the level of the water resource subsystem. The consistencies of Configurations 1 and 2 fluctuated above 0.9 from 2011 to 2016 and exhibited significant temporal changes from 2016 to 2020. A sharp declining trend was observed from 2016 to 2019, with Configuration 2 even falling below 0.75 in 2019. However, this situation only occurred in 2019, and Configuration 2 and was not randomly distributed, thus not constituting a benign deviation [29]. In 2020, the consistencies of both configurations surged dramatically. However, since the inter-group consistency adjustment distance did not exceed 0.1, it did not affect the overall explanatory capability. Therefore, the results of this study still possess strong applicability for assessing the factors influencing the level of the water resource subsystem under normal conditions.

Table 5. Adequacy analysis results of condition subsystem configuration.

Model	Ecological Environment—Social Subsystem or Ecological Environment—Economic Subsystem												
Configuration	Consistency		PRI		Coverage		Unique Coverage		Inter-Group Consistency Adjustment Distance	Intra-Group Consistency Adjustment Distance	Consistency Summary	PRI Summary	Coverage Summary
Ecological environment—social subsystem	0.913		0.823		0.556		0.043						
Cases	30	60	22	23	24	25	26	27	0.0908	0.1958			
	28	29	36	37	38	39	40	86					
	87	88	89	90	104	105	106	107					
	108	109	110								0.902	0.802	0.631
Ecological environment—economic subsystem	0.901		0.787		0.588		0.075						
Cases	21	96	97	98	22	23	24	25	0.0945	0.1958			
	26	27	28	29	36	37	38	39					
	40	86	87	88	89	90	104	105					
	106	107	108	109	110								

Table 6. Core and peripheral condition subsystems.

Condition Variable	Ecological Environment Subsystem—Social Subsystem Model or Ecological Environment—Economic Subsystem	
	Ecological Environment—Social Subsystem Model	Ecological Environment—Economic Subsystem
Ecological environment subsystem	●	●
Social subsystem	●	
Economic subsystem		●

Note: ● indicates the core subsystem, while a blank space signifies that either presence or absence is acceptable.

4.2.3. Intra-Group Results of Sufficiency Analysis

The intra-group consistency adjustment distances above 0.1 suggest that the explanatory power of the two configurations in the spatial dimension is weak, with a clear regional effect. Therefore, the coverage of the two configurations in each province and municipality is examined to reflect the geographic distribution of cases each configuration can explain. Specifically, the Yangtze River Economic Belt is divided into the Yangtze River Delta, Middle Yangtze, and Chengdu–Chongqing urban agglomerations. By observing the coverage of the two configurations in each urban agglomeration, the optimal explanatory regions for both configurations are explored. The results are shown in Table 7. Configurations 1 and 2 have the highest coverage in the Yangtze River Delta urban agglomeration, followed by the Chengdu–Chongqing and Middle Yangtze urban agglomerations. Table 7 also shows a significant difference in the coverage between Shanghai downstream and Chongqing upstream, unlike that of other provinces within the same urban agglomeration.

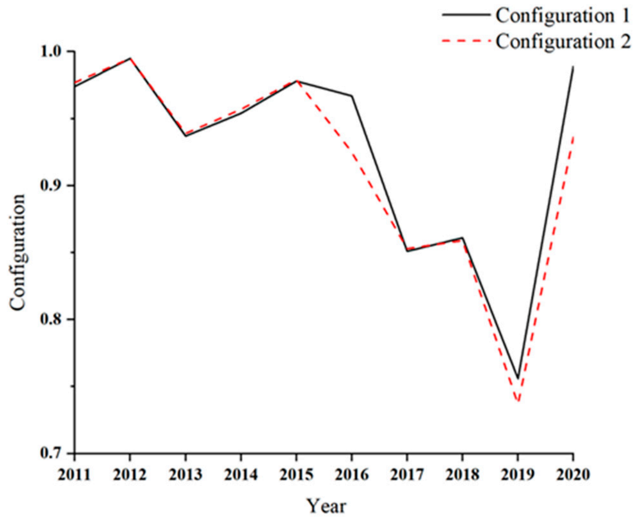

Figure 3. The variation trends of Configuration 1 (ecological environment subsystem–social subsystem) and Configuration 2 (ecological environment subsystem–economic subsystem) from 2011 to 2020. This is information is used to understand the changes in the impact of these two configurations on the water resource subsystem in the temporal dimension.

Table 7. Coverage of Configurations 1 and 2 in each province and municipality.

	Yangtze River Delta Urban Agglomeration				Middle Yangtze Urban Agglomeration			Chengdu Chongqing Urban Agglomeration			
	Shanghai	**Jiangsu**	**Zhejiang**	**Anhui**	**Jiangxi**	**Hubei**	**Hunan**	**Chongqing**	**Sichuan**	**Guizhou**	**Yunnan**
Coverage of Configuration 1	0.492	0.922	0.795	1	0.329	0.58	0.327	0.44	0.636	0.36	0.767
Average geographical coverage of configuration one	0.8023				0.412			0.5508			
Coverage of Configuration 2	0.586	0.922	0.639	1	0.444	0.5	0.269	0.498	0.636	0.811	0.812
Average geographical coverage of configuration 2	0.7868				0.40433			0.6893			

5. Discussion

5.1. Dynamic QCA and WRCC

In recent years, the QCA model has gradually been introduced into environmental science to address the interaction of multiple factors and to conduct multi-case analysis [45,46]. However, the application of dynamic QCA for panel data analysis has primarily been in the fields of digital economics [40], political science [47], and business management [48], while its utilization in environmental science remains limited. Dynamic QCA compares cases to identify potential patterns of factor interaction, thereby revealing causal relationships. It combines the inductive characteristics of quantitative analysis with the in-depth understanding trait of qualitative research [29] to provide enhanced guidance for clean production. Based on the concept of interoperability related to carrying capacity [15], this study introduces dynamic QCA into the WRCC field for the first time.

In this study, the WRCC system is divided into four perspectives, namely water resources, ecological environment, society, and economy [49], representing all participants of WRCC. In addition, a complete WRCC evaluation framework is constructed. Based on this framework, a comprehensive scoring method is used to construct time-series variables for the WRCC subsystem, the ecological, social, and economic subsystems were designated as condition subsystems, with the water resource subsystem as the outcome subsystem.

A dynamic QCA model is introduced for the first time in the field of WRCC research. Through a dynamic QCA, the necessity and sufficiency of the ecological, social, and economic subsystems for the water resource subsystem are evaluated. This study provides novel insights into the spatiotemporal dimension of the water resource subsystem, highlighting the indispensability of ecological, social, and economic subsystems. Furthermore, it emphasizes the sufficiency of configuration-based condition subsystems in ensuring a sustainable water resource management approach.

Interactions between WRCC subsystems analyzed in a previous study only considered single subsystem interactions [15]. Considering the interactive dependencies between subsystems, this study identifies the composite pathways through which the ecological environment, social, and economic subsystems influence the water resource subsystem level. Meanwhile, it provides a new perspective and methodology for other carrying capacity studies.

5.2. Necessity Analysis

According to the results of the necessity analysis, the economic and social development of the Yangtze River Economic Belt has little impact on the level of water resources, indicating a relatively good stability of water resources in the Yangtze River Economic Belt. The unique geographical location of the Yangtze River Economic Belt contributes to its good stability. It encompasses the world's third-largest river, the Yangtze, along with its numerous tributaries and expansive lakes such as Dongting Lake and Poyang Lake. These natural features ensure a sustainable water supply within the basin and play a crucial role in stabilizing and regulating water resources [50]. Furthermore, the Chinese government has implemented a series of policies and measures in water resource management, such as integrated river basin management, trans-regional water diversion projects (e.g., the South-to-North Water Transfer Project), pollution prevention in river basins, and the promotion of water conservation policies. These initiatives aim to ensure the sustainable use of water resources. The water resource management of the Yangtze River Economic Belt is becoming increasingly scientific and systematic, facilitating the reasonable allocation and efficient utilization of water resources [31].

In terms of both temporal and spatial dimensions, a strong ecological subsystem is an essential prerequisite for achieving a high level of water resource subsystem in the Yangtze River Economic Belt. Conversely, a vulnerable ecological subsystem is an indispensable condition for realizing a low level. This underscores the crucial role of environmental protection in sustaining water use and enhancing water levels in the area. Therefore, each province and municipality should intensify efforts to protect the ecological environment and promote a high level of water resources.

The analysis of situations in the spatial dimension that failed necessity tests on the Yangtze River Economic Belt showed that the conditioning subsystems significantly influence the outcome subsystems at a regional level. The province of Guizhou had the highest occurrences, with consistency exceeding 0.9. Even in scenario j, where the consistency fell below 0.9, it still reached 0.871, indicating that within the framework of WRCC, the ecological, social, and economic subsystems of Guizhou Province serve as necessary conditions for the water resource subsystem in both temporal and spatial dimensions. Regardless of the state of ecological, social, and economic subsystems, they will significantly influence the water resource subsystem, leading to either high or low levels. This highlights the remarkable sensitivity and dependence of Guizhou's water resource conditions on these three subsystems. The above findings suggest a substantial inefficiency in water resource management in Guizhou, necessitating an intensified effort by the provincial government [51], thereby fostering the coordinated development of the ecological environment, society, economy, and water resources. The government should utilize long-term interviews and remote sensing data to estimate river flow and ecological conditions [52]. Concurrently, it is essential to consider hydrogeological methods to simulate the impacts of water scarcity under various scenarios of climate change and overexploitation of water resources [53].

Developing risk maps for water scarcity in different regions can serve as a valuable tool to highlight areas with the highest risk levels [54]. Additionally, it is crucial to mobilize public participation to identify the most effective water-saving methods in specific fields. For instance, Surendran and his team combined classical irrigation efficiency experiments with farmer participation and concluded that "at the farmer scale, the LCDI method for sugarcane demonstrated significant advantages over other methods" [55]. In addition, due to the unique geographic and climatic characteristics of Guizhou, its distinctive karst topography and subtropical humid climate make hydrological conditions complex and variable. Water systems in karst areas differ from those in non-karst areas, with more complex and variable hydrological processes. Complex hydrogeological systems not only limit the number of analytical techniques and methods available to researchers but also constrain the accuracy of models and predictions [56]. To ensure the sustainable use of water resources in Guizhou, it is imperative for the provincial government to vigorously safeguard the ecological subsystem and build hydraulic infrastructure to mitigate the intense hydrological functions induced by the karst topography.

Based on the results of the necessity analysis, we can not only evaluate the temporal variations in water resource levels within the study area but also identify regions characterized by unstable water resource levels. Consequently, policymakers can effectively allocate limited water resources, enhance public awareness regarding water resource protection, and prompt regions with poor water resource levels to safeguard the ecological environment, develop new technologies, and innovate management strategies [57]. These techniques and strategies can subsequently be extended to other areas to optimize water resource management efficiency across the region.

5.3. Sufficiency Analysis

The summary results of the sufficiency analysis indicate that the ecological environment subsystem can form combinations with both social and economic subsystems, ultimately leading to a high level of the water resource subsystem through different paths that converge towards the same outcome. Both configurations include the ecological environment subsystem, demonstrating that a strong ecological environment subsystem can promote a high level of water resources. However, it is imperative to strengthen water resource management and protection to prevent potential impacts from the economic, social, and ecological environment subsystems. Otherwise, the water resource level could be passively influenced to maintain a high state.

Configuration 1, 'Ecological environment subsystem—social subsystem', and Configuration 2, 'Ecological environment subsystem—economic subsystem', can be considered as sufficient conditions for the emergence of a high-level water resource subsystem over time. These configurations exhibit strong explanatory power in the temporal dimension, independent of any significant time effects. A further analysis reveals that the stability of the water resource subsystem experienced a substantial increase between 2016 and 2019. However, in 2020, there was an abrupt decrease in the stability of the water resource subsystem, accompanied by a sudden rise in the influence exerted by economic, social, and ecological factors. Therefore, it is necessary to conduct a detailed analysis of the water resources, economic, social, and ecological environments of the Yangtze River Economic Belt from 2016 to 2020.

The rapid improvement in the stability of the water resource subsystem in 2016 suggests the effectiveness of the Chinese government's measures to protect the Yangtze River Basin, such as the 'Action Plan for the Prevention and Control of Water Pollution' launched on 16 April 2015. In 2016, General Secretary Xi Jinping emphasized the need to prioritize the restoration of the Yangtze River's ecological environment, advocating for extensive protection and discouraging aggressive development. In the following years, eleven provinces and municipalities along the Yangtze Economic Belt collaborated in pollution control and ecological restoration, synchronizing their efforts in the upper, middle, and lower reaches of the river. The intensive introduction of policies and regulations by multiple departments has enhanced the effectiveness of Yangtze River protection [58]. In 2018, the Ministry of Ecology and Environment and the National Development and Reform Commission jointly issued the 'Action Plan for the Battle for the Conservation and Restoration of the Yangtze River', which put forward eight major tasks in response to the key issues of water pollution in the Yangtze. This significantly improved the water environment of the Yangtze River, thereby reducing the impact of the economic, social, and ecological environmental subsystems on the water resource level. However, in 2020, the COVID-19 pandemic significantly influenced various industries, with indirect effects on the management and utilization of water resources. During the pandemic prevention and control, restrictions on environmental monitoring activities resulted in ineffective supervision of industrial pollution and domestic sewage treatment. The economic recession caused by the pandemic may have compelled certain companies to implement cost-cutting measures, leading to a reduction in their investment in pollution control and environmental protection, thus exacerbating the external pressures on water resources. The government may have allocated more resources and attention to the pandemic during this period, potentially leading to a relative decrease in the emphasis on environmental protection and water resource management, thereby weakening policy implementation. As a result, the strength of water resource management and protection was considerably weaker compared to the period from 2016 to 2019, resulting in a significant decrease in the stability of the water resource subsystem and an increased influence from the economic, social, and ecological subsystems. Given that the consistency-adjusted distance between groups remained below 0.1 without compromising the overall explanatory power, the findings of this study retain significant relevance to the normal state of the water resource subsystem. Therefore, it is imperative for provinces and municipalities along the Yangtze Economic Belt to intensify their efforts in protecting the ecological environment, implementing the Yangtze River Protection Law, and proactively enhancing their economic or social levels to promote the achievement of a high level of the water resource subsystem.

Configurations 1 and 2 cannot be regarded as sufficient conditions for the emergence of a high-level water resource subsystem in the spatial dimension. There exists a distinct regional effect on the summary consistency, indicating that these two configurations exert varying influences on the water resource levels across different regions. The underlying reason is the geographical span of the Yangtze Economic Belt, encompassing eleven provinces and municipalities across China from west to east. Due to different economic development needs, ecological environmental protection measures, social management, policy disparities, and public awareness and participation, there is a significant divergence in economic, social, and ecological environments [44].

A further analysis shows that Configurational 1 primarily accounts for cases in the Yangtze River Delta urban agglomeration, including Jiangsu, Zhejiang, Anhui, and the Chengdu–Chongqing urban agglomeration's Yunnan. Configurational 2 predominantly encompasses cases in Jiangsu and Anhui within the Yangtze River Delta, as well as Guizhou and Yunnan of the Chengdu–Chongqing urban agglomeration. Provinces and municipalities along the Yangtze River Economic Belt can enhance their respective condition subsystems based on their corresponding configurations to achieve a high-level water resource subsystem. For example, Yunnan, which satisfies the sufficient condition for a high level of water resources under both Configurational 1 and Configurational 2, possesses unique geographical and climatic conditions, rich biodiversity, and abundant water resources. However, it is also one of the most ecologically vulnerable areas [44]. Socio-economic activities, especially tourism and hydropower development, exert significant impacts on the environment and water resources. Compared with residents living in economically developed areas, local residents are less aware of water conservation and environmental protection. Therefore, it is imperative to formulate detailed management strategies and enhance resident awareness of water conservation and environmental protection through media campaigns, thus strengthening the protection of the ecosystem and ensuring the sustainability of local water resources. During the intra-group analysis, the level of water resources in the city cluster in the middle reaches of the Yangtze River was more stable than the other two urban agglomerations. The Mid-Yangtze urban agglomeration boasts numerous lakes, which serve as vital reservoirs for water storage and regulate climate, contributing to the stability of water resources. The construction of reservoirs such as the Three Gorges Dam reservoir in Hubei Province, the Yueyang development area reservoir in Hunan Province, and the Poyang Lake reservoir in Jiangxi has significantly enhanced water resource management and ensured their stability. In this regard, Sichuan, Guizhou, and Yunnan in the Chengdu–Chongqing urban agglomeration can draw valuable insights from the Mid-Yangtze urban agglomeration by constructing reservoirs to ensure the stability of regional water use.

Based on the sufficiency analysis results of condition configurations, we can observe the annual fluctuations in the stability of water resource levels in the Yangtze River Economic Belt. This provides a scientific basis for planning and managing regional water resources in the future, guiding the industrial layout, policy implementation, and economic structural adjustments. By examining corresponding cases for each configuration, guidance can be provided on how each province and municipality should develop to improve water resource levels.

5.4. The Particularity of Shanghai and Chongqing

As municipalities directly under the central government of China, Shanghai, and Chongqing hold a distinct administrative status that grants them greater economic and administrative autonomy compared to other provinces. In the necessity analysis, both municipalities exhibit consistency below 0.9 only in scenarios i and j, indicating that a strong economic subsystem is not a necessary condition for municipalities along the Yangtze River Economic Belt to possess high-level water resource subsystems and low-level water resource subsystems. This observation reflects the superior economic development of Chongqing and Shanghai as municipalities and regional economic centers compared to other provinces [42,59]. On the other hand, it also highlights the significant pressure on the region's water resources. In the sufficiency analysis of condition configurations, the coverage of Configuration 1 and Configuration 2 in Shanghai and Chongqing are both lower than that observed in other provinces within their respective urban clusters. This observation suggests that Configurations 1 and 2 have a limited impact on water resource levels in Shanghai and Chongqing, demonstrating that Shanghai and Chongqing have relatively well-established water resource management and protection policies and measures [60]. In conclusion, Shanghai and Chongqing are confronted with the scarcity of water resources and experience limited water availability. In order to address this challenge, the governments of cities should consider constructing water diversion facilities and obtaining water from adjacent provinces with abundant water resources through exchange or purchase. Such measures can alleviate the issue of water scarcity in Shanghai and Chongqing and foster economic development in neighboring provinces.

6. Conclusions

To address the issue of 'neglecting the interdependencies among subsystems' in previous research on interactions within the WRCC framework and to enhance the level of regional WRCC, this study introduced a dynamic QCA model. An in-depth analysis of the effects of the economic, social, and ecological environment subsystems on the water resource subsystem within the WRCC system is conducted. The model considers multiple synergistic pathways among subsystems, resolving the limitation of previous research in providing differentiated pathway choices, and offers a new method for investigating interactions among subsystems under the WRCC framework. Between 2011 and 2020, the status of water resources in the Yangtze River Economic Belt was unstable, and the management and protection of water resources remained inadequate due to influences from ecological, social, and economic factors. The protection of the ecosystem contributes significantly to the realization of high water resource levels. The effects of the ecological environment subsystem, social subsystem, and economic subsystem on high water resource levels and the sufficiency of configurations composed of these three subsystems are significant. A necessity analysis can be characterized on the basis of consistency, while a sufficiency analysis can be based on coverage to assess water resource conditions in different areas. Based on the results of the sufficiency analysis of condition configurations, provincial and municipal governments can strengthen corresponding subsystems and coordinate all subsystems to ensure the sustainable utilization of regional water resources. Furthermore, the management and protection of water resources should be strengthened to minimize the impact of the ecological environment subsystem, social subsystem, and economic subsystem on water resource levels, thus ensuring regional water resource stability. A limitation of this study is the exclusion of fuzzy data indicators in the selection process. Additionally, due to the lack of available data, the indicators we chose to construct the water resource carrying capacity (WRCC) framework do not comprehensively cover every aspect of water resources, society, economy, and the ecological environment. This shortcoming has, to some extent, constrained the accuracy of the dynamic QCA. Moreover, dynamic QCA can be applied to fuzzy set processing, suggesting that future studies could incorporate fuzzy data analysis. If the quality of WRCC is defined as a fuzzy set, dynamic QCA could be employed to explore the magnitude and pathways of the impact exerted by various subsystems under different WRCC frameworks.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w16203006/s1, Table S1: Current WRCC calculation method; Table S2: Index system for water resource carrying capacity of 11 provinces and cities in the Yangtze River Economic Belt; Supplement S2. References [61–86] are cited in Supplementary Materials S1.

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References

1. Bidlack, W.R.; Wang, W.; Clemens, R. Water The World's Most Precious Resource. *J. Food Sci.* **2004**, *69*, crh55–crh60. [CrossRef]
2. Conant, B.; Robinson, C.E.; Hinton, M.J.; Russell, H.A.J. A framework for conceptualizing groundwater-surface water interactions and identifying potential impacts on water quality, water quantity, and ecosystems. *J. Hydrol.* **2019**, *574*, 609–627. [CrossRef]
3. Meng, Y.; Wang, M.; Xu, W.; Guan, X.; Yan, D. Structure construction, evolution analysis and sustainability evaluation of Water-Ecological-Economic system. *Sustain. Cities Soc.* **2022**, *83*, 103966. [CrossRef]
4. Vörösmarty, C.J.; Rodríguez Osuna, V.; Cak, A.D.; Bhaduri, A.; Bunn, S.E.; Corsi, F.; Gastelumendi, J.; Green, P.; Harrison, I.; Lawford, R.; et al. Ecosystem-based water security and the Sustainable Development Goals (SDGs). *Ecohydrol. Hydrobiol.* **2018**, *18*, 317–333. [CrossRef]
5. Zhang, J.; Zhang, C.; Shi, W.; Fu, Y. Quantitative evaluation and optimized utilization of water resources-water environment carrying capacity based on nature-based solutions. *J. Hydrol.* **2019**, *568*, 96–107. [CrossRef]
6. Scanlon, B.R.; Fakhreddine, S.; Rateb, A.; de Graaf, I.; Famiglietti, J.; Gleeson, T.; Grafton, R.Q.; Jobbagy, E.; Kebede, S.; Kolusu, S.R.; et al. Global water resources and the role of groundwater in a resilient water future. *Nat. Rev. Earth Environ.* **2023**, *4*, 87–101. [CrossRef]
7. Brown, J.; Acey, C.S.; Anthonj, C.; Barrington, D.J.; Beal, C.D.; Capone, D.; Cumming, O.; Pullen, F.K.; MacDonald, G.J.; Hicks, B.; et al. The effects of racism, social exclusion, and discrimination on achieving universal safe water and sanitation in high-income countries. *Lancet Glob. Health* **2023**, *11*, e606–e614. [CrossRef]

8. Tang, W.; Pei, Y.; Zheng, H.; Zhao, Y.; Shu, L.; Zhang, H. Twenty years of China's water pollution control: Experiences and challenges. *Chemosphere* **2022**, *295*, 133875. [CrossRef]
9. Howells, M.; Hermann, S.; Welsch, M.; Bazilian, M.; Segerström, R.; Alfstad, T.; Gielen, D.; Rogner, H.; Fischer, G.; van Velthuizen, H.; et al. Integrated analysis of climate change, land-use, energy and water strategies. *Nat. Clim. Chang.* **2013**, *3*, 621–626. [CrossRef]
10. Yu, M.; Wang, C.; Liu, Y.; Olsson, G.; Wang, C. Sustainability of mega water diversion projects: Experience and lessons from China. *Sci. Total Environ.* **2018**, *619–620*, 721–731. [CrossRef]
11. Wang, G.; Xiao, C.; Qi, Z.; Meng, F.; Liang, X. Development tendency analysis for the water resource carrying capacity based on system dynamics model and the improved fuzzy comprehensive evaluation method in the Changchun city, China. *Ecol. Indic.* **2021**, *122*, 107232. [CrossRef]
12. Yang, X.; Sun, B.; Lei, S.; Li, F.; Qu, Y. A bibliometric analysis and review of water resources carrying capacity using rené descartes's discourse theory. *Front. Earth Sci.* **2022**, *10*, 970582. [CrossRef]
13. Wang, Y.J.; Yang, G.; Xu, H.L. Evaluation of Water Resources Carrying Capacity Based on Fuzzy Comprehensive Evaluation on River Basin in Arid Zone. *Adv. Mater. Res.* **2010**, *113–116*, 488–494. [CrossRef]
14. Gao, Y.; Liu, C. Threshold analysis of regional water resources development and utilization. *J. Water Resour.* **1997**, *8*, 73–79.
15. Wang, T.; Jian, S.; Wang, J.; Yan, D. Dynamic interaction of water–economic–social–ecological environment complex system under the framework of water resources carrying capacity. *J. Clean. Prod.* **2022**, *368*, 133132. [CrossRef]
16. Qin, W.; Wei, L.I. Research Progress and Prospect of Regional Resources and Environment Carrying Capacity Evaluation. *Ecol. Environ. Sci.* **2020**, *29*, 1487–1498. [CrossRef]
17. Peng, T.; Deng, H. Comprehensive evaluation on water resource carrying capacity in karst areas using cloud model with combination weighting method: A case study of Guiyang, southwest China. *Environ. Sci. Pollut. Res.* **2020**, *27*, 37057–37073. [CrossRef]
18. Wang, S.; Sun, X.; Zhong, S. Exploring the Multiple Paths to Improve the Construction Level of Digital Government: Qualitative Comparative Analysis Based on the WSR Framework. *Sustainability* **2023**, *15*, 9891. [CrossRef]
19. Al-Kalbani, M.S.; Price, M.F.; Abahussain, A.; Ahmed, M.; O'Higgins, T. Vulnerability Assessment of Environmental and Climate Change Impacts on Water Resources in Al Jabal Al Akhdar, Sultanate of Oman. *Water* **2014**, *6*, 3118–3135. [CrossRef]
20. Lijuan, D.; Yong, X.U. Review of Research Progress in Carrying Capacity of Water Resources. *Res. Soil Water Conserv.* **2015**, *22*, 341–348.
21. Wang, Z.; Fu, X. Scheme simulation and predictive analysis of water environment carrying capacity in Shanxi Province based on system dynamics and DPSIR model. *Ecol. Indic.* **2023**, *154*, 110862. [CrossRef]
22. Ragin, C.C. *The Comparative Method: Moving beyond Qualitative and Quantitative Strategies*; University of California Press: Berkeley, CA, USA, 1987.
23. Jang, J. Analysis of the Relationships between Early Childhood Policies and National Happiness Level: Application of Fuzzy Set Qualitative Comparative Analysis Method. *Korean Comp. Gov. Rev.* **2013**, *17*, 73–94. [CrossRef]
24. Greckhamer, T.; Furnari, S.; Fiss, P.C.; Aguilera, R.V. Studying configurations with qualitative comparative analysis: Best practices in strategy and organization research. *Strateg. Organ.* **2018**, *16*, 482–495. [CrossRef]
25. Seny Kan, A.K.; Adegbite, E.; El Omari, S.; Abdellatif, M. On the use of qualitative comparative analysis in management. *J. Bus. Res.* **2016**, *69*, 1458–1463. [CrossRef]
26. Hsieh, M. An Empirical Study of Education Divide Diminishment through Online Learning Courses. *EURASIA J. Math. Sci. Technol. Educ.* **2017**, *13*, 3189–3208. [CrossRef]
27. Sergis, S.; Sampson, D.G.; Giannakos, M.N. Supporting school leadership decision making with holistic school analytics: Bridging the qualitative-quantitative divide using fuzzy-set qualitative comparative analysis. *Comput. Hum. Behav.* **2018**, *89*, 355–366. [CrossRef]
28. Fang, Z. Determinants of Local Governments' Information Disclosure: A Dynamic QCA Analysis Based on Provincial Panel Data. *J. Intell.* **2023**, *42*, 133–141.
29. Garcia-Castro, R.; Ariño, M.A. A General Approach to Panel Data Set-Theoretic Research. *J. Adv. Manag. Sci. Inf. Syst.* **2016**, *2*, 63–76. [CrossRef]
30. Goodell, J.W.; Kumar, S.; Lahmar, O.; Pandey, N. A bibliometric analysis of cultural finance. *Int. Rev. Financ. Anal.* **2023**, *85*, 102442. [CrossRef]
31. Li, R.; Jin, W. The role of the Yangtze River Protection Law in the emergence of adaptive water governance in China. *Ecol. Soc.* **2023**, *28*, 32. [CrossRef]
32. Chen, P. Effects of the entropy weight on TOPSIS. *Expert. Syst. Appl.* **2021**, *168*, 114186. [CrossRef]
33. Ragin, C.C.; Strand, S.I. Using Qualitative Comparative Analysis to Study Causal Order: Comment on Caren and Panofsky (2005). *Sociol. Methods Res.* **2008**, *36*, 431–441. [CrossRef]
34. Rihoux, B.; Ragin, C.C. *Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques*; Sage Publications: Thousand Oaks, CA, USA, 2009; Volume 51.

35. Schneider, C.Q.; Wagemann, C. *Set-Theoretic Methods for the Social Sciences: A Guide to Qualitative Comparative Analysis*; Cambridge University Press: Cambridge, UK, 2012.
36. Haibo, T.; Ziteng, F.; Du, Y. Technical Management Capability, Attention Allocation, and Local Government Website Construction: A Configuration Analysis Based on TOE Framework. *Manag. World* **2019**, *35*, 81–94.
37. Chen, L.; Li, Y.; Fan, D. How do emerging multinationals configure political connections across institutional contexts? *Glob. Strateg. J.* **2018**, *8*, 447–470. [CrossRef]
38. Ren, C.; Guo, P.; Li, M.; Li, R. An innovative method for water resources carrying capacity research—Metabolic theory of regional water resources. *J. Environ. Manag.* **2016**, *167*, 139–146. [CrossRef]
39. Yunzhou, D.; Liangding, J. Configuration perspective and qualitative comparative analysis (QCA): A New Path for Management Research. *Manag. World* **2017**, *6*, 155–167.
40. Zhang, Z.; Ou, G.; Elshkaki, A.; Liu, R. Evaluation of Regional Carrying Capacity under Economic-Social-Resource-Environment Complex System: A Case Study of the Yangtze River Economic Belt. *Sustainability* **2022**, *14*, 7117. [CrossRef]
41. Xu, Y.; Yang, L.; Zhang, C.; Zhu, J.Q. Comprehensive evaluation of water ecological environment in watersheds: A case study of the Yangtze River Economic Belt, China. *Environ. Sci. Pollut. Res.* **2023**, *30*, 30727–30740. [CrossRef]
42. Xu, B.; Liu, Y. Primary Evaluation of the Economic Losses Caused by Water Pollution in Shanghai by Classification Approach. *Arch. Environ. Prot.* **2013**, *39*, 67–74. [CrossRef]
43. Wang, Z.; Duan, P.; Akamatsu, T.; Chen, Y.; An, X.; Yuan, J.; Lei, P.; Li, J.; Zhou, L.; Liu, M.; et al. Riverside underwater noise pollution threaten porpoises and fish along the middle and lower reaches of the Yangtze River, China. *Ecotoxicol. Environ. Safe* **2021**, *226*, 112860. [CrossRef]
44. Wang, Y.; Huo, Z.; Li, D.; Zhang, M. Evaluation of Common Prosperity Level and Regional Difference Analysis along the Yangtze River Economic Belt. *Int. J. Environ. Res. Public Health* **2022**, *19*, 11851. [CrossRef] [PubMed]
45. Avoyan, E. Collaborative Governance for Innovative Environmental Solutions: Qualitative Comparative Analysis of Cases from Around the World. *Environ. Manag.* **2023**, *71*, 670–684. [CrossRef] [PubMed]
46. Xie, L.; Xu, T.; Ju, T.; Xia, B. Explaining the alienation of megaproject environmental responsibility behavior: A fuzzy set qualitative comparative analysis study in China. *Eng. Constr. Archit. Manag.* **2022**, *30*, 2794–2813. [CrossRef]
47. Zhang, X.; Ma, W.; Sheng, S. Understanding the structure and determinants of economic linkage network: The case of three major city clusters in Yangtze River Economic belt. *Front. Environ. Sci.* **2023**, *10*, 1073395. [CrossRef]
48. Meirong, Z.; Rui, L. Exploration of High Quality Development Path for Manufacturing Enterprises: Based on NCA and Dynamic QCA Methods. *Financ. Account. Mon.* **2024**, *45*, 123–128. [CrossRef]
49. Zhao, Y.; Wang, Y.; Wang, Y. Comprehensive evaluation and influencing factors of urban agglomeration water resources carrying capacity. *J. Clean. Prod.* **2021**, *288*, 125097. [CrossRef]
50. Gong, G.; Zhao, Y. Ecology versus economic development: Effects of China's Yangtze River Economic Belt strategy. *Int. Stud. Econ.* **2024**, *19*, 330–352. [CrossRef]
51. Sun, F.; Miao, C.; Li, S.; Shen, J.; Huang, X.; Zhang, S. Dynamic Evaluation of Water Resources Management Performance in the Yangtze River Economic Belt. *Sustainability* **2024**, *16*, 649. [CrossRef]
52. Gallart, F.; Llorens, P.; Latron, J.; Cid, N.; Rieradevall, M.; Prat, N. Validating alternative methodologies to estimate the regime of temporary rivers when flow data are unavailable. *Sci. Total Environ.* **2016**, *565*, 1001–1010. [CrossRef]
53. De Filippis, G.; Foglia, L.; Giudici, M.; Mehl, S.; Margiotta, S.; Negri, S.L. Seawater intrusion in karstic, coastal aquifers: Current challenges and future scenarios in the Taranto area (southern Italy). *Sci. Total Environ.* **2016**, *573*, 1340–1351. [CrossRef]
54. Fernandes, M.R.; Segurado, P.; Jauch, E.; Ferreira, M.T. Riparian responses to extreme climate and land-use change scenarios. *Sci. Total Environ.* **2016**, *569–570*, 145–158. [CrossRef] [PubMed]
55. Surendran, U.; Jayakumar, M.; Marimuthu, S. Low cost drip irrigation: Impact on sugarcane yield, water and energy saving in semiarid tropical agro ecosystem in India. *Sci. Total Environ.* **2016**, *573*, 1430–1440. [CrossRef] [PubMed]
56. Friesen, J.; Rodriguez Sinobas, L.; Foglia, L.; Ludwig, R. Environmental and socio-economic methodologies and solutions towards integrated water resources management. *Sci. Total Environ.* **2017**, *581–582*, 906–908. [CrossRef] [PubMed]
57. Kungolos, A.; Di Nardo, A.; Mallios, Z.; Manakou, V.; Emmanouil, C. Effective environmental management within the context of sustainability and economic development: A special issue from the 13th International Conference on Protection and Restoration of the Environment (PREXIII), 3–8 July 2016, Mykonos island, Greece. *Environ. Sci. Pollut. Res.* **2018**, *25*, 26695–26698. [CrossRef] [PubMed]
58. Li, Z.; Guo, J.; You, X. A study on spatio-temporal coordination and driving forces of urban land and water resources utilization efficiency in the Yangtze River Economic Belt. *J. Water Clim. Chang.* **2023**, *14*, 272–288. [CrossRef]
59. Tian, P.; Wu, H.; Yang, T.; Jiang, F.; Zhang, W.; Zhu, Z.; Yue, Q.; Liu, M.; Xu, X. Evaluation of urban water ecological civilization: A case study of three urban agglomerations in the Yangtze River Economic Belt, China. *Ecol. Indic.* **2021**, *123*, 107351. [CrossRef]
60. Yan, X.; Chen, H. Evaluation on Water Resource Carrying Capacity Based on BP Model—A Case Study in Guanzhong District. In Proceedings of the 2011 International Conference on Ecological Protection of Lakes-Wetlands-Watershed and Application of 3S Technology (EPLWW3S 2011), Nanchang, China, 25–26 June 2011.

61. Gao, Y.; Zhang, H.M.; Xu, G.W.; Su, H.M.; Zhang, Y. Sustainable Utilization Evaluation on Water Resources Base on Matter Element Analysis in Huaibei City. *Adv. Mater. Res.* **2012**, *610–613*, 2671–2674. [CrossRef]
62. Gao, H.; Sun, L. Grey Clustering Evaluation of Water Resources Carrying Capacity Based on Triangle Whitening Weight Function. *IOP Conf. Ser. Earth Environ. Sci.* **2018**, *208*, 12101. [CrossRef]
63. Tang, B.; Hu, Y.; Li, H.; Yang, D.; Liu, J. Research on comprehensive carrying capacity of Beijing–Tianjin–Hebei region based on state-space method. *Nat. Hazards* **2016**, *84*, 113–128. [CrossRef]
64. Zhang, J.; Wang, C.; Wang, X.; Yang, L. The study of water resources carrying capacity in kaifeng city based on support vector machines. In Proceedings of the International Conference on Informational Technology and Environmental System Science, Jiaozuo, China, 15–17 May 2008.
65. Zhang, Z.; Lu, W.X.; Zhao, Y.; Song, W.B. Development tendency analysis and evaluation of the water ecological carrying capacity in the Siping area of Jilin Province in China based on system dynamics and analytic hierarchy process. *Ecol. Model.* **2014**, *275*, 9–21. [CrossRef]
66. Chi, M.; Zhang, D.; Fan, G.; Zhang, W.; Liu, H. Prediction of water resource carrying capacity by the analytic hierarchy process-fuzzy discrimination method in a mining area. *Ecol. Indic.* **2019**, *96*, 647–655. [CrossRef]
67. Fu, Q.; Liu, D.; Wang, Z. Evaluation of Region Water Resources Carrying Capacity Based on Set Pair Analysis Technology. In Proceedings of the 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing, Dalian, China, 12–14 October 2008; pp. 1–4.
68. Wang, W.; Zeng, W. Optimizing the Regional Industrial Structure Based on the Environmental Carrying Capacity: An Inexact Fuzzy Multi-Objective Programming Model. *Sustainability* **2013**, *5*, 5391–5415. [CrossRef]
69. Zhang, Y.; Li, S.S. The Time-Series Study of Xiangjiang River Water Carrying Capacity Based on the Ecological Footprint of Water Resource—The ChangZhuTan Region, for Example. *Adv. Mater. Res.* **2012**, *518–523*, 4362–4370. [CrossRef]
70. Wang, C.; Hou, Y.; Xue, Y. Water resources carrying capacity of wetlands in Beijing: Analysis of policy optimization for urban wetland water resources management. *J. Clean. Prod.* **2017**, *161*, 1180–1191. [CrossRef]
71. Li, B.; Wang, X.; Wei, T.; Zeng, Y.; Zhang, B. Analysis of sustainable utilization of water resources in karst region based on the ecological footprint model—Liupanshui city case. *J. Water Supply Res. Technol. Aqua* **2018**, *67*, 566–575. [CrossRef]
72. Dai, D.; Sun, M.; Xu, X.; Lei, K. Assessment of the water resource carrying capacity based on the ecological footprint: A case study in Zhangjiakou City, North China. *Environ. Sci. Pollut. Res.* **2019**, *26*, 11000–11011. [CrossRef]
73. Yang, Q.; Wang, H.; Mu, H.; Luo, J.; Bao, X.; Bian, J.; Delgado Martín, J. Risk assessment of water resources and environmental carrying capacity in Yinchuan city. *Hum. Ecol. Risk Assess.* **2019**, *25*, 120–131. [CrossRef]
74. Wang, S.; Xu, L.; Yang, F.; Wang, H. Assessment of water ecological carrying capacity under the two policies in Tieling City on the basis of the integrated system dynamics model. *Sci. Total Environ.* **2014**, *472*, 1070–1081. [CrossRef]
75. Yang, J.; Lei, K.; Khu, S.; Meng, W.; Qiao, F. Assessment of water environmental carrying capacity for sustainable development using a coupled system dynamics approach applied to the Tieling of the Liao River Basin, China. *Environ. Earth Sci.* **2015**, *73*, 5173–5183. [CrossRef]
76. Song, X. Evaluation of water resources carrying capacity based on system dynamics model. In Proceedings of the 3rd International Conference on Economic, Business Management and Education Innovation (EBMEI), Prague, Czech Republic, 10–11 May 2016.
77. Fang, H. Application of System Dynamics and WCCI in Water Resources Evaluation: Taking Pakistan as an Example. In Proceedings of the 2nd International Conference on Mechanical, Electronic, Control and Automation Engineering (MECAE 2018), Qingdao, China, 30–31 March 2018; Advances in Engineering Research. Atlantis Press: Dordrecht, The Netherlands, 2018; Volume 149, pp. 14–19.
78. Sun, B.; Yang, X. Simulation of Water Resources Carrying Capacity in Xiong'an New Area Based on System Dynamics Model. *Water* **2019**, *11*, 1085. [CrossRef]
79. Chen, N.X.; Qu, J.H.; Xu, J.X.; Li, Z.P.; Yang, L. Evaluation of Groundwater Environment Carrying Capacity Based on Catastrophe Theory. In Proceedings of the 2010 4th International Conference on Bioinformatics and Biomedical Engineering, Chengdu, China, 18–20 June 2010; pp. 1–4.
80. Song, F.; Yang, X.; Wu, F. Catastrophe progression method based on M-K test and correlation analysis for assessing water resources carrying capacity in Hubei province. *J. Water Clim. Chang.* **2020**, *11*, 556–567. [CrossRef]
81. Cheng, K.; Fu, Q.; Meng, J.; Li, T.X.; Pei, W. Analysis of the Spatial Variation and Identification of Factors Affecting the Water Resources Carrying Capacity Based on the Cloud Model. *Water Resour. Manag.* **2018**, *32*, 2767–2781. [CrossRef]
82. Lu, F.; Xu, J.; Wang, Z. Application of GA optimized wavelet neural networks for carrying capacity of water resources prediction. In Proceedings of the 2009 International Conference on Environmental Science and Information Application Technology, Wuhan, China, 4–5 July 2009; pp. 308–311.
83. Jianjun, W. Comprehensive evaluation and analysis method for carrying capacity of water resource based on Neural Network. In Proceedings of the International Conference on Intelligent Computation Technology & Automation, Nanchang, China, 14–15 June 2015; pp. 305–308.
84. Gulishengmu, A.; Yang, G.; Tian, L.; Pan, Y.; Huang, Z.; Xu, X.; Gao, Y.; Li, Y. Analysis of Water Resource Carrying Capacity and Obstacle Factors Based on GRA-TOPSIS Evaluation Method in Manas River Basin. *Water* **2023**, *15*, 236. [CrossRef]

85. Sun, X.; Zhou, Z.; Wang, Y. Water resource carrying capacity and obstacle factors in the Yellow River basin based on the RBF neural network model. *Environ. Sci. Pollut. Res.* **2023**, *30*, 22743–22759. [CrossRef]
86. Zhi, X.; Anfuding, G.; Yang, G.; Gong, P.; Wang, C.; Li, Y.; Li, X.; Li, P.; Liu, C.; Qiao, C.; et al. Evaluation of the Water Resource Carrying Capacity on the North Slope of the Tianshan Mountains, Northwest China. *Sustainability* **2022**, *14*, 1905. [CrossRef]

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