STUDY ON THE ASSESSMENT AND MANAGEMENT OF WATER RESOURCES CARRYING CAPACITY OF ECONOMIC COOPERATION ORGANIZATION IN THE PEARL RIVER BASIN, CHINA

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Abstract. As the basis for human survival and development, water resources play an important role in social sustainability, natural environmental protection and high-quality economic development. Water resources utilization needs to be controlled within certain thresholds, therefore, a reasonable assessment and management of water resources carrying capacity (WRCC) has key significance. This study focuses on the Basin Economic Cooperation Organization, taking the cities in the organization as the smallest unit. Driving - Pressure - State - Impact – Response (DPSIR) model, entropy value - technique for order Preference by Similarity to ideal solution (TOPSIS) model, spatial autocorrelation analysis, and GeoDetector model are used for analyzing the WRCC, spatial agglomeration characteristics, and influencing factors, respectively. The results indicate that WRCC ranges between 0.1 and 0.8, exhibiting significant differences among cities. The study area exhibits significant agglomeration with regard to the spatial characteristics. High-High, High-Low, Low-Low agglomeration are observed in two, one, and three cities, respectively. Meanwhile, spatial variation in the WRCC acts as a function of both single factors and interactions between multiple factors, and the single factor influences are clustered in the driving force system and pressure system. In addition, this study presents management recommendations for the interval range, spatial characteristics and influencing factors of the carrying level of cities in Basin Economic Cooperation Organization.
Keywords: *DPSIR, entropy value-improved TOPSIS model, spatial characteristics, Geodetector*

Introduction

Water is the basic resource for the survival of all animals and plants on earth (Du et al., 2019), and an important medium for the continuation and development of human civilization (Zheng and Angelakis, 2018). Water resources are used in various activities such as agricultural irrigation (Han et al., 2023), industrial production (Liu and Peng, 2020), urban water supply (Yang et al., 2019a), etc., which provide key support for the development of cities along the basin. However, with the expansion of population size and urbanization, water resources are overused, wasted and polluted (Ye, 2020). When water resources are exploited and utilized beyond a certain threshold, it can cause environmental degradation (Qi and Luo, 2005) and social conflict (Tatar et al., 2022), which in turn threatens the building of human civilization. Therefore, there is a necessity for a rational assessment of water resource carrying capacity (WRCC) and effective management of water resources.

Carrying capacity is often used to describe the maximum pressure or load that an ecosystem can withstand without causing irreversible damage. Initial research on carrying capacity aimed to study the constraints of food on human society (Short, 1998). With the publication of the “Limits to Growth” report (Mikesell, 1995), the research on

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carrying capacity has gradually expanded to different fields, such as land-water resources (Sun et al., 2020), mineral resources (He et al., 2020), and ecological resources (Chen et al., 2020; Swiader et al., 2020). The views of relevant institutions and scholars can be categorized into three theories. Scale theory highlights the maximum extent of water utilization based on the total of water resources, which can be pooled together for social, economic, and environmental development (Daneshmand et al., 2014). Maximum population theory emphasizes factors such as the availability, quality and distribution of water resources to identify the size of the population that can be supported (Guo and Wang, 2023). Capacity theory underlines factors such as water demand, infrastructure and management systems, and it ensures optimal utilization levels that meet people’s needs and do not undermine long-term benefits (Chen and Tang, 2023). These theoretical frameworks provide insight and guidance to policymakers. By considering scale, population capacity and capacity needs, they can ensure the continued exploitation of water resources while safeguarding human survival, livelihoods and productive progress.

The concept of WRCC was introduced to counter the problems of water scarcity, water pollution, and serious flooding in China (Mou and Liu, 1994). Afterwards, WRCC had been widely used to measure water resources in cities (Zhao et al., 2021; Zhi et al., 2022), provinces (Wei et al., 2023), basins (Meng et al., 2022) and other scopes. In recent years, many scholars have researched the WRCC assessment and made recommendations for water resource management applications based on the assessment (Buytaert et al., 2012). These related studies on WRCC can be divided into microscopic and macroscopic research perspectives.

Under the micro perspective, scholars mainly construct specific models to measure the specific status of water resources (e.g., runoff, water quality, etc.) of micro-individuals (e.g., reservoirs, rivers, lakes, etc.), and then combine the research results with recommendations for water resources management and water resources application (*Fig. 1*). Chang combined the stormwater management model and the Vollenweider model to investigate the pollution sources of water quality in the Baoshan Reservoir, which led to the application of recommendations to reduce total phosphorus loads (Chang and Yu, 2020). Yang predicted runoff from Danjiangkou Reservoir through a hybrid model (Yang et al., 2019b). Peng described the application of POSA to three lakes in Yunnan and demonstrated that POSA can effectively regulate the water environment during implementation (Jiayu et al., 2020). Yu et al. applied hydrodynamic and salinity mathematical models to the EBINUR LAKE water recharge process and demonstrated that this recharge process has a positive effect on halophytes and lake ecology (Yu et al., 2018). Ovchinnikov et al. proposed a management scheme for the mine by analyzing the role of mine water flow on the drainage system (Ovchinnikov and Zyryanov, 2023). Duan et al. carried out the relationship between supply, demand and benefits under the comprehensive consideration of water resources on the wetland and irrigated area and sought the best recharge scheme to maximize the benefits (Duan et al., 2019). Rafiei et al. based on the integrated model of surface water-groundwater in the wetland, made simulations of the wetland water exchange process to make simulation and propose water quality improvement schemes for wetlands (Rafiei et al., 2022). However, some of the processes in Rafiei’s study are worth thinking about, such as the high degree of hydrological heterogeneity of the 28 wetland sites which requires process and holistic thinking when measuring and managing them. In the study of water resources micro, although some micro studies can solve specific problems, the

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correlation and synthesis of ecosystems are neglected, such as the correlation between individuals and individuals, and the correlation between individual water resources and ecological, economic, social and other elements.

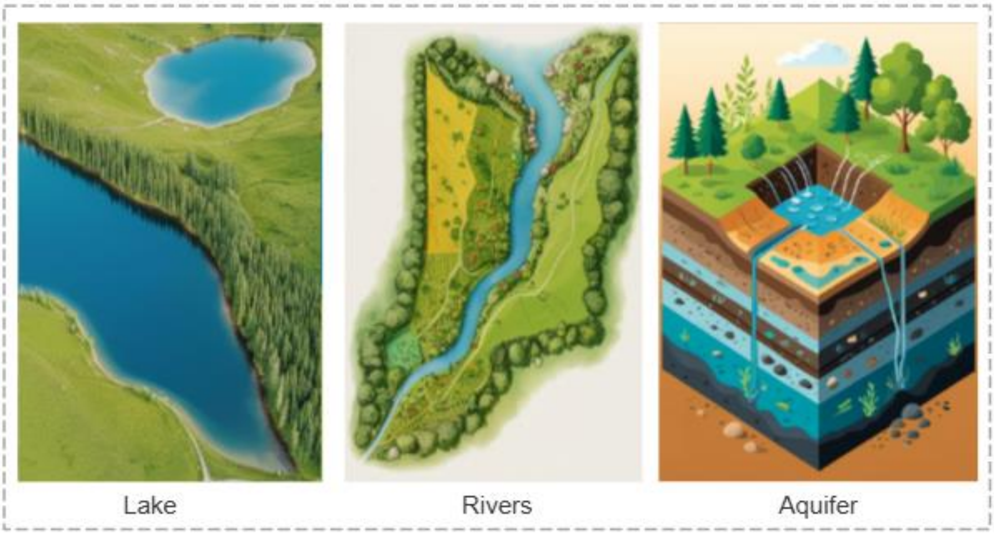

Figure 1. *Scope of water resources research from a micro perspective*

In the macro perspective research, due to the holistic and systematic nature of the research object (e.g., city, watershed, province, etc.), scholars are able to synthesize all kinds of factors involved in water resources, select reasonable indicators, use subjective or objective evaluation methods to measure WRCC, and put forward the corresponding strategies for optimal management of water resources (*Fig. 2*).

An appropriate evaluation system plays a key role in indicator selection. It is generally recognized that economic systems, social systems, water resource systems, ecosystems and WRCC are highly interconnected (Wang et al., 2022). Therefore, these four element systems and their extensions are commonly utilized as the principles for WRCC's indicator selection and system construction. Secondly, the "support-pressure" and its extension model, based on internal stability factors and external influences in water resource systems, is used as one of the bases for indicator selection (Sun et al., 2022). In addition, water resources, water environment and water ecology as interrelated systems, which constitute the complete water system, can also be used as the basis for the WRCC establishment (Zhou et al., 2023). However, these systems have the problems of lack of systematicity and weak theoretical history. DPSIR theoretical model, as a basis for the establishment of the indicator system, is able to synthesize the whole process of occurrence, evolution and solution of environmental problems, and has the characteristics of systematicity and comprehensiveness. Therefore, the DPSIR model is selected as the basis for the selection of WRCC evaluation indicators in this research.

DPSIR was first utilized to build an ecological carrying capacity rating system. Subsequently, scholars not only optimized the process chain of the DPSIR model, but also improved its applicability. Nowadays, the DPSIR model is widely used to design carrying capacity indicators for the ecological environment (Robele Gari et al., 2015), tourism environment (Swangjang and Kornpiphat, 2021), climate resources (Hu and He,

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2018), land-water resources (Schjonning et al., 2015), and agricultural resources (Binimelis et al., 2009). Therefore, the DPSIR model is suitable for evaluating the WRCC of basins both theoretically and practically.

Figure 2. *Urban water cycle mapping*

In terms of evaluation methods, three methods have been used to determine WRCC, namely: empirical estimation model, comprehensive index model, and complex system analysis. The fuzzy comprehensive evaluation method has generally been used in combination with the principal component analysis to avoid the interference of subjective factors (Ren et al., 2020). Meanwhile, the system dynamics model (Yang and Wang, 2022), technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) model (Dang et al., 2023), back propagation neural network (Liu et al., 2019), and multi-objective analysis (Dong et al., 2021) are commonly used complex system analysis methods.

In the WRCC management, the factors that constrain the level of WRCC in the region need to be identified and the water resources need to be managed in an integrated manner and be allocated efficiently. grey-relational analysis (Wang et al., 2021), obstacle-degree model (Dang et al., 2023), multivariable linear regression model (Liu et al., 2023), and geographical detectors (Geodetector) (Wang and Xu, 2017) are the commonly used methods. Geodetector is effective in combining spatial features to identify the influencing factors compared to other tools. Therefore, Geodetector is selected as a tool for identifying the influencing factors of WRCC in this research.

In summary, previous studies on WRCC focused on both micro and macro perspectives. The micro-study perspective focuses more on the solution of water resource specific problems, such as water quality and runoff, but neglects the holistic and comprehensive nature of the environmental system. The research on WRCC in a

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macro perspective avoids such problems. In this study, the DPSIR model is used as the basis for the WRCC indicator selection, which helps to understand the interaction and feedback mechanism between different levels. In addition, entropy-TOPSIS evaluation method is adopted for WRCC evaluation. Finally, Geodetector is used to identify and understand the root causes of water resource problems in the basin and their potential impacts, which provide deeper thinking and solutions to effectively address water resource challenges (*Fig. 3*).

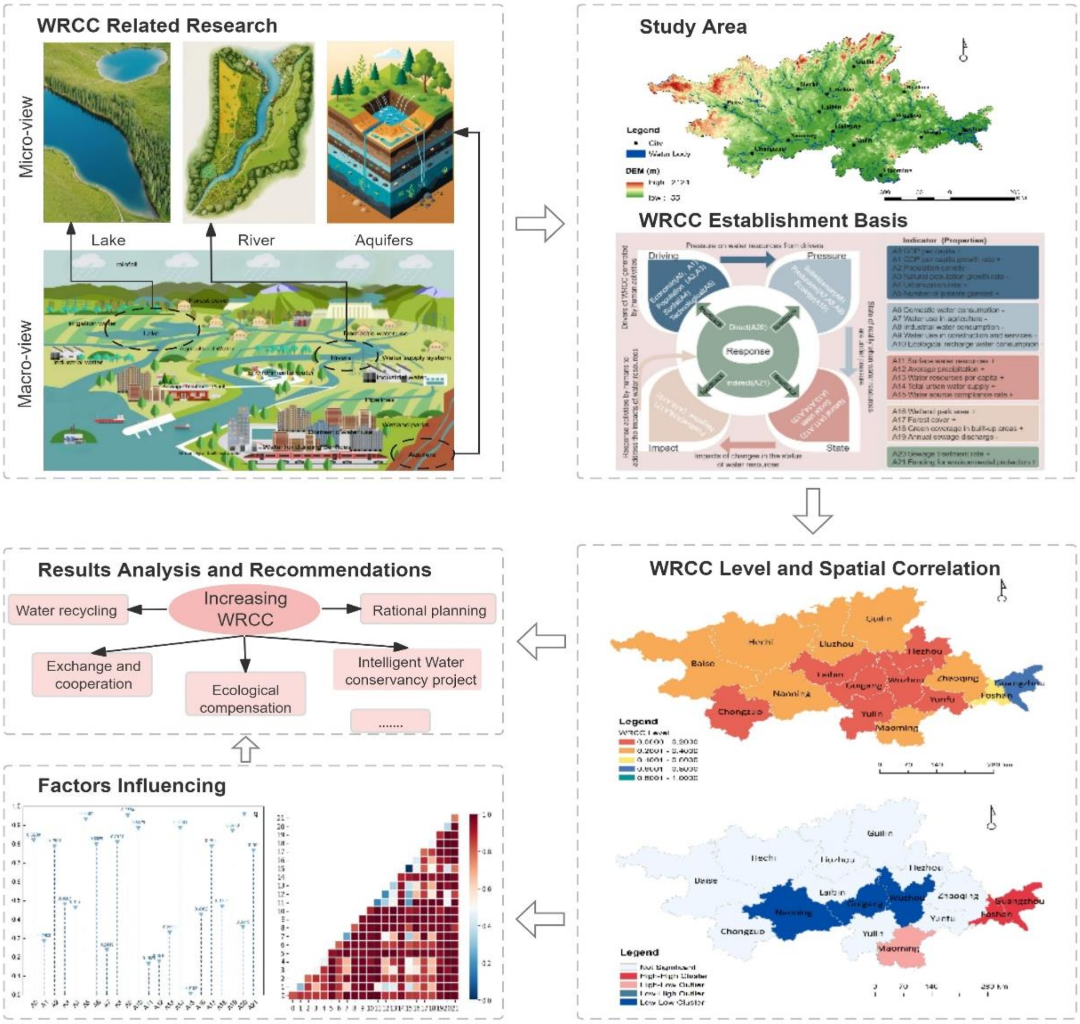

Figure 3. *Research ideas. (Location of relevant original subfigures: upper left subfigure corresponds to Figures 1 and 2, upper right subfigure corresponds to Figures 4, 5 and Table 1, lower right subfigure corresponds to Figures 6 and 7, lower left subfigure corresponds to Figure 8)*

Area

Study area

The Pearl River-West River Economic Belt (PR-WR EB) is an essential part of the Southern China Basin Economic Cooperation Organization, which is also a key region in the West River and Pearl River. The study area of this research takes the city as the smallest unit, including 16 cities including Guangzhou, Nanning, Guilin, Foshan,

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Liuzhou, and so on (*Fig. 4*). These cities have a high level of water resources due to the high-water yield of the West River and the Pearl River. However, with urbanization and economic development, some cities have serious problems of water pollution and water waste, such as industrial discharges, urban wastewater, high water consumption, etc. Based on this, there is a need to analyze the WRCC with the city as the smallest unit and to make recommendations according to the factors affecting the level of WRCC.

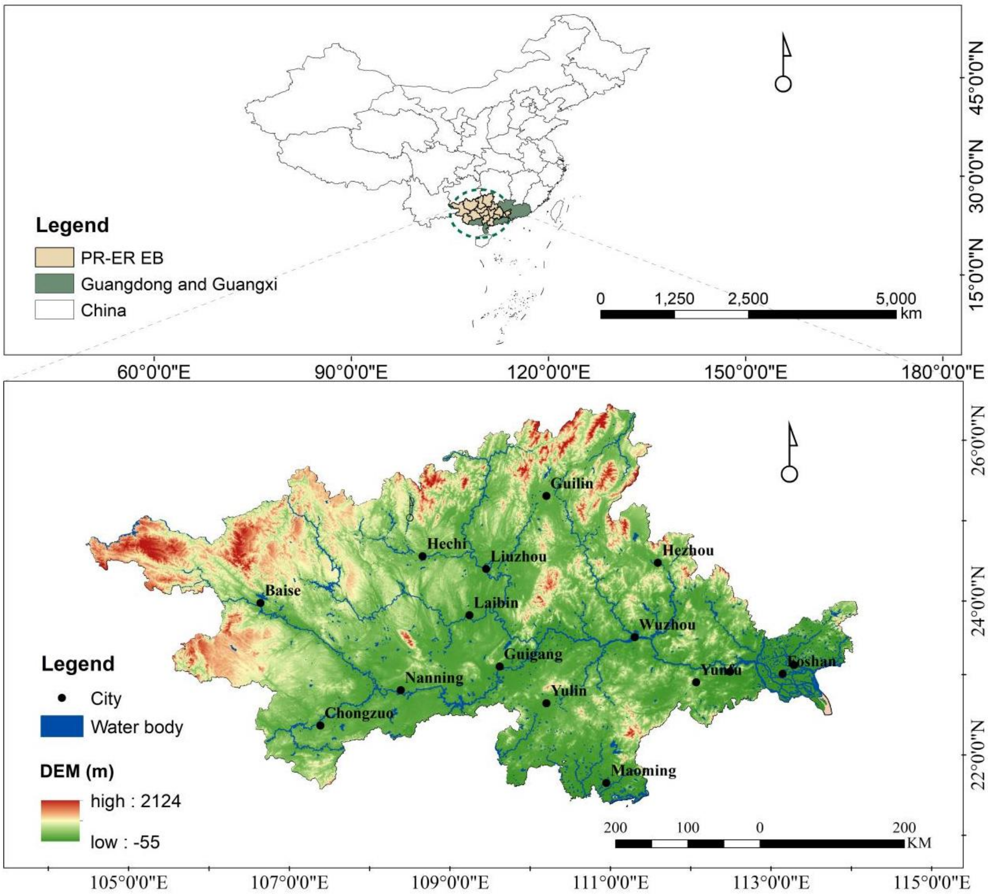

***Figure 4.** Location map and Elevation map of the Pearl River-West River Economic Belt. ("PR-ER EB" stands for Pearl River-West River Economic Belt; "City" stands for cities included in the Pearl River-West River Economic Belt and their locations)*

Data sources

In this paper, the data from 2021 have been used, which include datasets from official published resources such as Guangxi Statistical Yearbook 2022, Guangdong Statistical Yearbook 2022, Guangdong Water Resources Bulletin 2021, Guangxi Water Resources Bulletin 2021, and water resources bulletins for municipalities.

Materials and methods

Indicator selection

This study utilizes the DPSIR model and the principles of system, science, representativeness, and universality to construct an indicator system for WRCC

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evaluation. By combining the measurability of indicators and the actual situation of PR-WR EB, this research utilizes 22 indicators to form an indicator layer and evaluate WRCC (*Fig. 5; Table 1*).

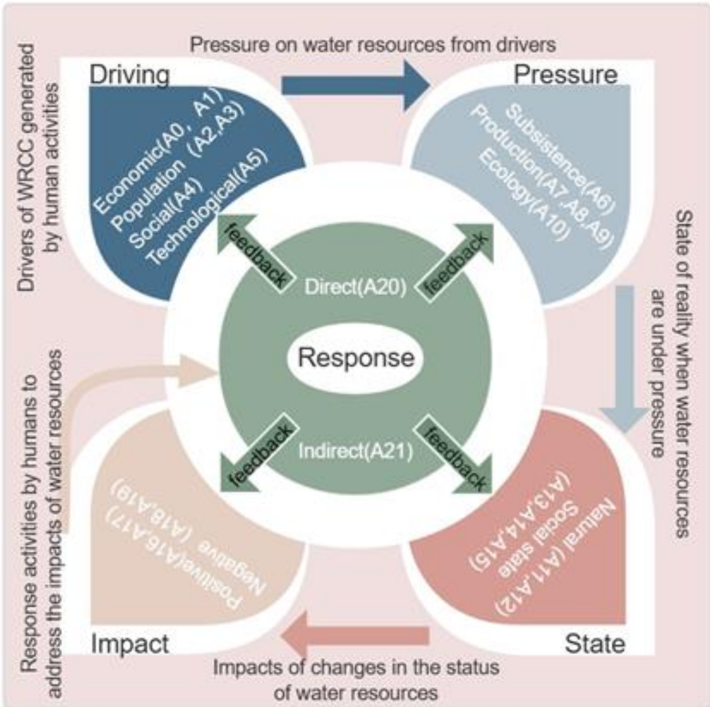

Figure 5. *The driving–pressure–state– impact–response model and its feedback process*

Table 1. *WRCC indicators based on the driving–pressure–state–impact–response model*

System	Indicator (properties)	References
Driving	A0 GDP per capita (+)	(Mou et al., 2020; Cheng et al., 2016)
	A1 GDP per capita growth rate (+)	(Mou et al., 2020; Wang et al., 2019)
	A2 Population density (-)	(Mou et al., 2020; Cheng et al., 2016)
	A3 Natural population growth rate (-)	(Mou et al., 2020; Lu et al., 2019)
	A4 Urbanization rate (+)	(Cheng et al., 2016; Zhang et al., 2023)
	A5 Number of patents granted (+)	(Gibson et al., 2015; Spearing et al., 2023)
Pressure	A6 Domestic water consumption (-)	(Wang et al., 2019; Lu et al., 2019)
	A7 Water use in agriculture (-)	(Wei et al., 2019; Wang and Fu, 2023)
	A8 Industrial water consumption (-)	(Wang et al., 2019; Zhang et al., 2023)
	A9 Water use in construction and services (-)	(Feng et al., 2019)
	A10 Ecological recharge water consumption (-)	(Wang et al., 2019)
State	A11 Surface water resources (+)	(Zhang et al., 2023)
	A12 Average precipitation (+)	(Zhang et al., 2023)
	A13 Water resources per capita (+)	(Mou et al., 2020; Zhang et al., 2023)
	A14 Total urban water supply (+)	(Wang and Fu, 2023)
	A15 Water source compliance rate (+)	(Mou et al., 2020; Wei et al., 2019)
Impact	A16 Wetland park area (+)	(Wang and Fu, 2023)
	A17 Forest cover (+)	(Cheng et al., 2016; Mou et al., 2020)
	A18 Green coverage in built-up areas (+)	(Zhang et al., 2023)
	A19 Annual sewage discharge (-)	(Gao et al., 2014)
Response	A20 Sewage treatment rate (+)	(Cheng et al., 2016; Wang et al., 2019)
	A21 Funding for environmental protection (+)	(Mou et al., 2020; Wang and Fu, 2023)

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Research methodology

Entropy value-improved TOPSIS method

The TOPSIS method ranks the evaluation objects based on their proximity to the desired goal. Meanwhile, the improved TOSIS method can effectively avoid data subjectivity, and objectively portray the degree of influence of multiple impact indicators, which facilitates accurate evaluation of the object score. The improved TOPSIS method utilizes the following steps (Chen, 2019):

Step 1: Original data are standardized

For positive indicators, standardized using *Equation 1*.

$$X_j = \frac{x_j - MIN\,x_j}{MAX\,x_j - MIN\,x_j} + A \quad \text{(Eq.1)}$$

For negative indicators, standardized using *Equation 2*.

$$X_j = \frac{MAX\,x_j - x_j}{MAX\,x_j - MIN\,x_j} + A \quad \text{(Eq.2)}$$

where x_j is the original value, $MAXx_j$ and $MINx_j$ denote the max and min values, respectively; and A is a constant and has been assigned a value of 0.0001; processed values for all indicators ranged from 0.0001 to 1.0001.

Step 2: Indicator weights are determined using the steps below.

First, the weight of the j indicator P_j is determined through *Equation 3*.

$$P_j = \frac{X_j}{\sum_{j=1}^{n} X_j} \quad \text{(Eq.3)}$$

where *j = 1,2,...,m; m* is the index number.

Second, the entropy value of the *j-th* indicator H_j is calculated through *Equation 4*.

$$H_j = -k \sum_{j=1}^{n} P_j \ln P_j \quad \text{(Eq.4)}$$

where $k = \frac{1}{\ln n}$ and $H_j \geq 0$.

Third, the variance rate E_j is determined by *Equation 5*.

$$E_j = 1 - H_j \quad \text{(Eq.5)}$$

Finally, the resulting calculation results are normalized and the corresponding entropy weight coefficient W_j is calculated by *Equation 6*.

$$W_j = \frac{E_j}{\sum_{j=1}^{n} E_j} \quad \text{(Eq.6)}$$

Step 3: Closeness is calculated using the steps below.

First, the weighting matrix Z_{ij} is calculated through *Equation 7*.

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$$Z_{ij} = X_{ij} \times W_j \tag{Eq.7}$$

where $i = 1,2,...,n$. $j = 1,2,...,m$; n is the number of cities; m is the number of indicators.

Second, calculating the distance D^+ and D^- from the evaluation object to the positive and negative ideal solutions by *Equations 8*, *9*, *10*, and *11*.

$$Z^+ = \{MAXZ_{ij} | i = 1,2, ..., n\} = \{Z_1^+, Z_2^+, ... Z_n^+\} \tag{Eq.8}$$

$$Z^- = \{MINZ_{ij} | i = 1,2, ..., n\} = \{Z_1^-, Z_2^-, ... Z_n^-\} \tag{Eq.9}$$

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(Z_j^+ - Z_{ij}\right)^2} \tag{Eq.10}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(Z_j^+ - Z_{ij}\right)^2} \tag{Eq.11}$$

Finally, calculating the closeness of the object to the ideal solution by *Equation 12.*

$$T_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{Eq.12}$$

where $0 \leq T_i \leq 1$.

This study divides the WRCC closeness into five levels based on Chinese standard for carrying capacity (*Table 2*).

Table 2. *Criteria for grading WRCC*

T_i	(0,0.2]	(0.2,0.4]	(0.4,0.6]	(0.6,0.8]	(0.8,1]
WRCC Criteria	Grade V (Red alert)	Grade IV (Orange Alert)	Grade III (Yellow Alert)	Grade II (Blue Alert)	Grade I (Green Alert, i.e., No Alert)

Spatial autocorrelation analysis

(1) Global

Moran's I, a measure of spatial autocorrelation, is used to measure the global spatial correlation of spatial datasets. Moran's I helps in determining whether the WRCCs show a spatial tendency to be clustered or dispersed (Griffith and Chun, 2018). Calculation of Moran's Index using *Equation 13.*

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n}(y_j - \bar{y})^2} \tag{Eq.13}$$

where n represents the number of minimum units of study, i and j denote the minimum units of study.

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(2) Local

The degree of local spatial correlation in each region can be measured by calculating the *Getis-Ord Gi* statistic (Griffith and Chun, 2018). Using *Equations 14* and *15* to calculate the *Getis-Ord Gi*.

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} y_i w_{ij}(d) y_j}{\sum_{i=1}^{n}\sum_{j=1}^{n} y_i y_j} \tag{Eq.14}$$

$$Z(G) = \frac{G - E(G)}{\sqrt{VAR(G)}} \tag{Eq.15}$$

where d represents the spatial distance between any two cities, w_{ij} denotes the spatially distant weight matrix, y_i and y_j are WRCC level of the i-th and j-th city, respectively, $Z(G)$ is a standardized result of G, $E(G)$ is the expected value, and $\sqrt{VAR}$ is the standard deviation.

GeoDetector

This paper utilizes Geodetector to determine the extent to which influencing factors affect spatial variation in WRCC. Geodetector can effectively reveal the differences between geographic units and identify the factors that influence the differences between geographic units (Wang and Xu, 2017). In this paper, the WRCC between the minimum study units (cities), if there are differences in WRCC, are able to identify the extent of the influence of the explanatory variables (WRCC indicators) on WRCC by using Geodetector. The formula is as follows (*Eq. 16*):

$$q = 1 - \frac{\sum_{h=1}^{l} N_h \delta_h^2}{N\sigma^2} \tag{Eq.16}$$

where q denotes the impact level. m and n represent the number of indicators and the number of minimum study units, respectively, and ∂ is the standard deviation of the WRCC of the minimum study unit.

Results

Indicator weights

This study utilizes the entropy method to explore both the contribution and importance of each indicator to WRCC, which can effectively judge the relative importance of each indicator or factor to WRCC, that is, the strength of the explanation. The results are shown in *Table 3*.

WRCC level

The study applies the improved TOPSIS method to calculate the closeness of WRCC values in PR-WR EB, and the WRCC grade is determined based on the closeness. The results are shown in *Figure 6*.

Based on the results, it can be seen that all cities have a WRCC between Grade II (Blue Alert) and grade V (Red Alert). Among the cities, the WRCC level located at Grade II (blue alert) is Guangzhou (0.7541). The city located at Grade III (yellow alert) is Foshan (0.4447). There are seven cities located in Grade IV (Orange Alert),

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according to WRCC from highest to lowest are Guilin (0.2750), Maoming (0.2574), Zhaoqing (0.2465), Liuzhou (0.2456), Nanning (0.2327), Hechi (0.2162) and Baise (0.2007). Cities located in Grade V (Red Alert) are also seven, according to the WRCC from highest to lowest are Chongzuo (0.1779), Wuzhou (0.1766), Hezhou (0.1748), Laibin (0.1691), Yunfu (0.1549), Guigang (0.1212), Yulin (0.1209). Guangzhou and Foshan are able to remain sustainable due to the scientific allocation and rational utilization of water resources. Water recycling centers in all cities in Grade IV are in overload and there is a mismatch between water supply and demand. Moreover, economic and social development has imposed pressure on the sustainable use of water resources, which has a negative impact on the sustainable development of Grade IV cities. WRCC in Grade V cities are severely excessive and a serious imbalance is observed between water supply and demand, which is in an unsustainable situation.

Table 3. *Indicator weights of WRCC*

Indicator	Weight	Indicator	Weight
A0	0.061356	A11	0.045371
A1	0.013422	A12	0.036531
A2	0.016048	A13	0.064755
A3	0.03101	A14	0.133803
A4	0.050312	A15	0.0103
A5	0.187251	A16	0.082022
A6	0.013449	A17	0.022683
A7	0.015309	A18	0.01387
A8	0.011208	A19	0.012496
A9	0.00956	A20	0.014829
A10	0.011126	A21	0.143289

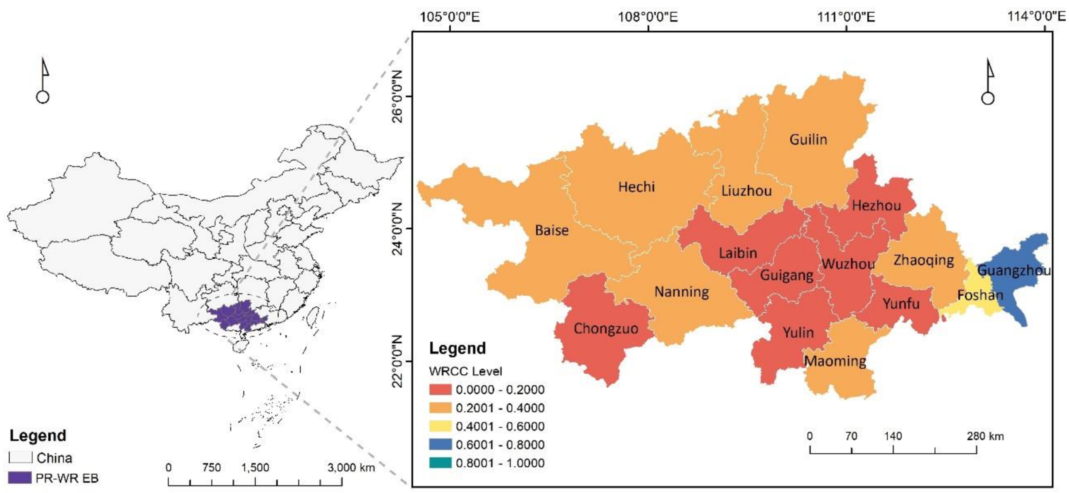

Figure 6. *WRCC Level of Cities in PR-WR EB, 2021. ("PR-ER EB" stands for Pearl River-West River Economic Belt)*

Furthermore, the WRCC of PR-WR EB exhibits the following sequence: downstream cities > upstream cities > midstream cities. In *Figure 4*, the downstream cities (e.g. Guangzhou and Foshan) are in the blue and yellow alerts, while the

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midstream cities (e.g. Guigang, Laibin, Wuzhou, Yulin, etc.) are in the red alert stage, and the upstream cities (e.g. Baise, Hechi, etc.) are in the orange alert stage. In addition, according to *Figure 4,* cities with similar WRCC levels show the phenomenon of spatial "grouping", so it is speculated that there is a spatial aggregation of urban WRCC, and the speculation is verified by using the Moran's I.

Spatial characteristic

In order to verify the conjecture that there is a geospatial "clustering" of WRCC in the region, this study selects the global Moran's I for verification, and the results are shown in *Table 4*. In 2021, the global Moran index of WRCC is 0.4224, which is higher than 0, indicating that the WRCC shows the characteristic of aggregation in geospatial space, which means that there is the "grouping" phenomenon. In addition, the P-value is 0.000059, which is lower than 0.01, and the Z-value is 4.017652, which is higher than 2.58, and passes the 0.01 significance test at the confidence level. This indicates that the clustering characteristics are significant, and the phenomenon of "grouping" is obvious. This may be explained by the fact that there will be agglomeration characteristics due to geographically close cities with a similar natural state of water resources (e.g. precipitation), as well as the fact that close cities are more similar economically, socially, and demographically, which will drive water resources in a similar way.

Table 4. *Global spatial autocorrelation results in PR-WR EB, 2021*

Summary	Value
Global Moran's I	0.422426
Z	4.017652
p-value	0.000059

Further analyzing WRCC aggregation types in geospatial space, it can be seen based on *Figure 7* that the main aggregation types are high - high aggregation, high - low agglomeration, low - low aggregation and insignificant. Of these, non-significant accounted for the largest proportion. The high - high agglomeration area is mainly located in the eastern part of the study area, where the WRCC is shown at the grade II and grade III (above medium) level. The high - low agglomeration is mainly located in the southeastern part of the study area, with WRCC showing a grade IV level. The low-low agglomeration is mainly located in the middle region of the study area and the WRCC is exhibited at grade IV and V (lower) levels. Cities with low value agglomerations are more likely to affect nearby cities and need to be prioritized when managing them.

Influencing factors of spatial differences in WRCC

In order to investigate the key factors affecting the spatial differences in WRCC, this study utilizes ArcGIS to classify the indicators used for WRCC evaluation, and then uses Geodetector to calculate the q-value of each indicator, and to filter and rank the factors influencing spatial differences in WRCC, all factors are ranked in *Table 5*. Ranking the top 10 is a factor that has a significant impact. The major indicators influencing are clustered in the Driving and Pressure factors. The calculated q-values show that the strongest influencing factors are water use in construction and services sectors (0.9554) and patent granting (0.9362). Furthermore, total urban water supply (0.8903), water consumption for ecological recharge (0.8879), annual sewage discharge (0.8743), GDP per capita (0.8238), industrial water consumption (0.8137), and per capita water consumption for domestic use (0.8029) are also powerful influencing factors. Forest cover (0.7925) and population density (0.7924) are also influential factors for spatial differences in WRCC.

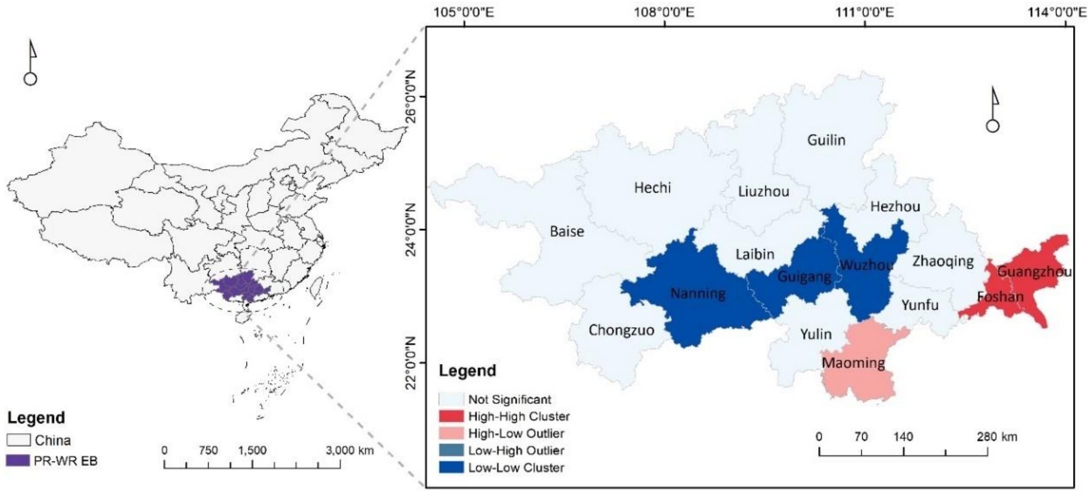

***Figure 7.** Local spatial autocorrelation results in PR-WR EB, 2021. ("PR-ER EB" stands for Pearl River-West River Economic Belt)*

***Table 5.** Ranking of Influencing factors in PR-WR EB, 2021*

Rank	Indicator	q statistic	p value	Rank	Indicator	q statistic	p value
1	A9	0.9554^{***}	0.0000	12	A3	0.4864	0.1897
2	A5	0.9362^{***}	0.0000	13	A18	0.4734	0.2443
3	A14	0.8903^{**}	0.0153	14	A4	0.4670	0.2245
4	A10	0.8879^{**}	0.0135	15	A16	0.4302	0.2364
5	A19	0.8743^{**}	0.0241	16	A20	0.3615	0.6190
6	A0	0.8238^{**}	0.0142	17	A13	0.3345	0.3746
7	A8	0.8137^{*}	0.0974	18	A1	0.2903	0.5613
8	A6	0.8029^{**}	0.0241	19	A7	0.2419	0.8463
9	A17	0.7925^{**}	0.0283	20	A12	0.1816	0.7765
10	A2	0.7924^{**}	0.0268	21	A11	0.1684	0.9513
11	A21	0.7690	0.1971	22	A15	0.0102	0.9677

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Interaction probes have been used to Identify factors affecting variances in WRCC, the detection results are shown in *Figure 8*. There are 231 two-by-two interactions, of which 190 have a q-value of 0.8 or more. The interaction between recharge water consumption and per capita water resources has the largest q-value of 0.9999. The interactions among impact factors are either two-way augmented or nonlinearly augmented relationships, while no independent, one-way nonlinearly attenuated, or

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nonlinearly attenuated relationships are observed. Of the 231 interactions, 14 are nonlinear enhancement relationships and 217 are two-way enhancement relationships.

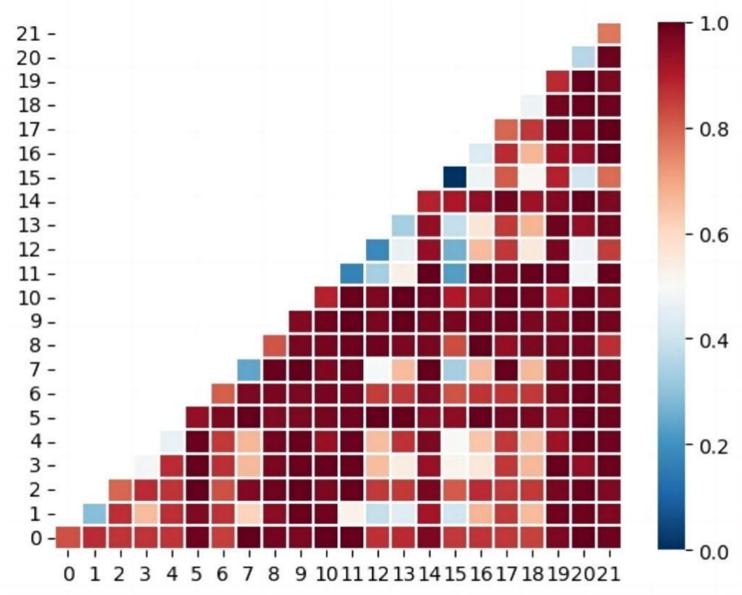

Figure 8. *Combined effect of two factors on WRCC in PR-WR EB, 2021*

Conclusion and discussion

Discussion

The PR-WR EB is an essential economic region in southern China, and WRCC is one of the key factors governing urban economic, social and ecological coordination along the route. So as to guarantee permanent development of regional ecology and comprehensively explore the problems associated with regional water resources, a comprehensive evaluation of WRCC is necessary. The results have been analyzed as follows:

(1) WRCC exhibits significant variability among cities. In particular, downstream cities (Guangzhou and Foshan) are able to effectively drive changes in WRCC with regard to the technological, social, and economic aspects, thereby resulting in better allocation and scientific utilization of water resources. Downstream cities can provide more financial support for recycling water resources and investing toward environmental protection. Furthermore, there is a need to enhance recycling capacity, which will guarantee that the economy, society, and population together contribute toward WRCC. Among the upstream and midstream cities, the WRCCs of Nanning, Guilin, and Liuzhou are not excessive because of potential economic and social drivers. However, the WRCCs of most cities in the middle reaches are severely overloaded. The availability of water resources is limited in midstream cities such as Laibin and Guigang, which rank low in terms of average precipitation, surface water resources, and urban water supply, thereby severely restricting the development of urban WRCC.

(2) A significant agglomeration is observed in the spatial distribution of WRCC, and there types of agglomeration are observed: H-H, H-L, and L-L agglomerations. This indicates that within PR-WR EB, the WRCCs of dissimilar cities are similar. In other words, cities with higher WRCC tend to be adjacent to cities with higher WRCC and

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vice-versa. The high spatial concentration of 16 cities along the PR-WR EB is a result of the *Pearl River-West River Economic Belt Development Plan*, which has resulted in deeper economic interactions and social exchanges among cities within PR-WR EB as well as stronger influence factors among cities.

(3) Furthermore, cities within the H-H and L-L agglomeration regions exhibit high and low WRCCs, respectively. There exist obvious spatial variations in WRCCs for cities within H-L agglomeration regions; that is, some areas have a high WRCC, while others have a low WRCC. Guangzhou has outstanding advantages in terms of geography, economy, policies, and natural conditions; therefore, it has a high WRCC. Foshan is in close proximity to Guangzhou and is influenced by it in terms of economic development. Meanwhile, it has obvious advantages in terms of natural resources and geographical location, and its WRCC is equally good; thus, agglomeration is high in Foshan. The three cities within the L-L agglomeration region are Nanning, Guigang, and Wuzhou. These cities are inferior in terms of average precipitation, surface water resources, and urban water supply, thereby being less useful to peripheral cities; hence, the agglomeration is low in these cities.

Overall, the single factor influences are clustered within the Driving and Pressure factors. Pressure imposed by tertiary water use on water resource systems and the driving force offered by technology are the most important reasons behind the differences in WRCC across cities. Meanwhile, most of the influencing factors have a greater impact on WRCC when they interact, and differences in urban WRCC mainly arise due to these interactions. Since the q-value of the interaction between water consumption for ecosystem recharge and per capita water resources is the largest, WRCC will be further increased when the water recharge and per capita water supply are harmonized.

Conclusion

This study employs the DPSIR causality model as the basis for determining WRCC indicators, evaluates WRCC by using the improved TOPSIS method, and elucidates the spatial differences in the WRCC of each city and the related influencing factors via a spatial autocorrelation analysis and GeoDetector. The following conclusions have been obtained:

Overall, the WRCC of the 16 cities along the PR-WR EB lies between 0.1 and 0.8. The only cities on blue and yellow alerts are Guangzhou and Foshan, respectively. There are seven cities on orange alert and seven cities on red alert. Meanwhile, the following sequence is observed for WRCC: downstream cities > upstream cities > midstream cities.

In addition, as verified by Moran’s index, the WRCCs of the 16 cities in the study area have a significant geospatial “grouping” phenomenon, which means that they are significantly clustered. In terms of the agglomeration type, the local autocorrelation analysis reveals that two cities, one city, and three cities exhibit H-H agglomeration (Guangzhou and Foshan), H-L clustering (Maoming), and L-L agglomeration (Nanning, Guigang, and Wuzhou).

The indicators influencing the spatial differences are primarily clustered among the Driving (D) and Pressure (P) factors. The main influencing indicators are A9 and A5. The results of the interaction probes show that the differences in WRCC arise mainly due to the interactions between multiple factors, and most of the influencing factors have a greater effect on WRCC when they interacted. The interaction between water

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consumption for ecosystem recharge and per capita water resources has the largest q-value, while having the most profound effect on the differences in WRCC.

Recommendation

Through further discussion about results, some relevant recommendations are given for improving WRCC and achieve sustainable development in PR-WR EB:

(1) Different measures should be adopted for each city to augment the WRCC of PR-WR EB.

For cities on blue and yellow alert, economic, social, and technological aspects assume a more prominent position in increasing WRCC. Therefore, “Strengths-based development” must be used to capitalize on the strengths of these cities or areas, which can be manifested into the increased construction of intelligent water conservancy projects (Chen et al., 2023), use of big data and artificial intelligence (Gohil et al., 2021), real-time monitoring of water supply and demand (de Souza Groppo et al., 2019), optimization of water resource scheduling and management, as well as improvement in the efficiency and accuracy of utilization.

For cities on orange alert, the differences in WRCC mainly arise due to economic and technological drivers. Therefore, the midstream cities can increase exchanges and cooperation with research institutes, universities (Alsaluli et al., 2015), and enterprises to promote continuous innovation in the science and technology associated with water resources, thereby leading to more efficient utilization (Seah and Lee, 2020). Meanwhile, it is imperative to facilitate the synergistic effect of WRCC and economic development, make rational use of the public-private-partnership model, and give ecological compensation to areas where WRCC has been increased (Dong and Liu, 2020).

For cities on red alert, “State” is a major barrier to lowering the alert level; thus, WRCC can be enhanced via supply and planning. On the one hand, there is a need to diversify the water resource supply, and enhance the diversity variety in utilizing water resources by making use of rainwater, wastewater, recycled water, and other water resources (Lyu et al., 2016; Bauer et al., 2019). On the other hand, the relevant departments need to formulate reasonable medium-term and long-term goals for water resource planning. By accurately assessing the situation of water resources to establish scientific goals, water resource management can be improved (Cai et al., 2004; Gallego-Ayala and Juizo, 2014).

(2) The WRCC of PR-WR EB presents significant agglomeration characteristics in space, thereby indicating a close relationship between the WRCCs of cities. Therefore, to address the imbalance in WRCC, the spatial diffusion effect needs to be effectively utilized. The application of technology, education, economic, and ecological diffusion effects for enhancing the WRCC is a comprehensive approach.

In technology diffusion, advanced water resource management technologies can be introduced in economically better-off regions; subsequently, the adoption and diffusion of this technology in other regions can be promoted through experience sharing (Shah et al., 1995).

In education diffusion, knowledge and experience in the field of water resource management can be diffused trans-regionally through exchanges, training and co-operation. Experience sharing among universities, research institutes, and expert teams within PR-WR EB can be promoted, and regular meetings can be held to

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facilitate the dissemination of knowledge regarding the use and protection of water resources (Cho et al., 2018).

In economic diffusion, successful cases of improved water resource management and utilization are used to attract additional investment and resources, thereby promoting local community economic growth and employment opportunities. This not only helps enhance people's quality of life but also provides valuable insights for environmental protection and water resource conservation. These cyclical effects set a precedent for future resource management and societal development.

In ecological diffusion, protection of water sources is taken care of (Gao et al., 2023). Meanwhile, the influence brought about by pollution sources on water quality is reduced, and the water quality in midstream and downstream are improved. Forest protection and sand prevention models are employed to protect mountain vegetation, reduce soil erosion, and maintain a sustainable supply of water resources.

(3) Based on the factors influencing spatial differences in WRCC, both single-factor effects and multi-factor interactions influence spatial differences in water resources. Therefore, the study uses this as a basis for making proposals on the root causes and structural problems associated with water resources.

From the perspective of a single factor, reducing the spatial differences in WRCC requires to scale down in the water consumption of the tertiary sector and an upgradation of the education level. On the one hand, the effectiveness of tertiary water utilization has been increased through the installation of water-saving equipment, enhanced maintenance and management of water-using equipment, recycling and recovery wastewater, and the rational use of water features and landscaping. On the other hand, the influence of regional education levels on WRCC is being increased through improved public education on water resources, support for water-related research and innovation in the scientific community, training activities associated with water management, and the development of related specializations.

From the perspective of the interaction between multiple factors, rational planning and management are a must. It is essential to ensure that the water demand of the ecological environment is met, while people are guaranteed adequate water supply; this will ensure that the relationship between all the involved parties is coordinated and that WRCC is enhanced.

In conclusion, this study explores the present position, spatial differences, and WRCC influencing factors. It also effectively addresses the existing problems, and puts forward suggestions for regional coordinated development. Meanwhile, the study follows the principle of problem orientation and adopts a scientific and reasonable methodological system to study the WRCC of inter-district basins through literature combing. During the construction of the indicator system, different principles, DPSIR theory, and a variety of factors are considered. Thus, the proposed system can be applied to other fields for both theoretical and practical applications.

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REFERENCES

[1] Alsaluli, A., Ahmed, A., Davies, J. (2015): Public engagement in integrated urban water management in Saudi Arabia: teachers' perceptions in relation to water awareness. – Water Science and Technology-Water Supply 15(4): 871-880.
[2] Bauer, S., Behnisch, J., Dell, A., Gahr, A., Leinhos, M., Linke, H. J., Shen, W., Tolksdorf, J., Wagner, M. (2019): Water reuse fit for purpose by a sustainable industrial wastewater management concept. – Chemie Ingenieur Technik 91(10): 1472-1479.
[3] Binimelis, R., Monterroso, I., Rodriguez-Labajos, B. (2009): Catalan agriculture and genetically modified organisms (GMOs) - an application of DPSIR model. – Ecological Economics 69(1): 55-62.
[4] Buytaert, W., Friesen, J., Liebe, J., Ludwig, R. (2012): Assessment and management of water resources in developing, semi-arid and arid regions. – Water Resources Management 26(4): 841-844.
[5] Cai, X. M., Lasdon, L., Michelsen, A. M. (2004): Group decision making in water resources planning using multiple objective analysis. – Journal of Water Resources Planning and Management 130(1): 4-14.
[6] Chang, C.-L., Yu, Z.-E. (2020): Application of water quality model to analyze pollution hotspots and the impact on reservoir eutrophication. – Environmental Monitoring and Assessment 192: 495.
[7] Chen, D., Zhou, Q.-G., Yu, L. (2020): Response of resources and environment carrying capacity under the evolution of land use structure in Chongqing Section of the Three Gorges Reservoir Area. – Journal of Environmental Management 274: 111169.
[8] Chen, J., Tang, X. (2023): Towards sustainable cities: studying evaluation index of water environment carrying capacity. – Water Resources Management 37(15): 5919-5938.
[9] Chen, P. (2019): Effects of normalization on the entropy-based TOPSIS method. – Expert Systems with Applications 136: 33-41.
[10] Chen, Z., Xu, J., Ma, Y., Zhang, Z. (2023): Application of data mining technology and intelligent information technology in the construction and management of the water conservancy project in Area A. – Water Supply 23(8): 3285-3296.
[11] Cheng, J., Zhou, K., Chen, D., Fan, J. (2016): Evaluation and analysis of provincial differences in resources and environment carrying capacity in China. – Chinese Geographical Science 26(4): 539-549.
[12] Cho, I., Park, J., Heo, E. (2018): Measuring knowledge diffusion in water resources research and development: the case of Korea. – Sustainability 10(8).
[13] Daneshmand, F., Karimi, A., Nikoo, M. R., Bazargan-Lari, M. R., Adamowski, J. (2014): Mitigating socio-economic-environmental impacts during drought periods by optimizing the conjunctive management of water resources. – Water Resources Management 28(6): 1517-1529.
[14] Dang, X., Zhao, X., Kang, Y., Liu, X., Song, J., Zhang, Y. (2023): Analysis of carrying capacity and obstacle factors of water resources in Longnan City, China, based on driving-pressure-state-response and technique for order preference by similarity to an ideal solution models. – Water 15(14).
[15] De Souza Groppo, G., Costa, M. A., Libanio, M. (2019): Predicting water demand: a review of the methods employed and future possibilities. – Water Supply 19(8): 2179-2198.
[16] Dong, Q., Liu, X. (2020): The legal norms of ecological compensation in coastal cities under regional cooperation. – Journal of Coastal Research 103:552-555.
[17] Dong, Z., Yang, G., Feng, S., Ma, J., Li, B. (2021): Analysis of the ultimate water resources carrying capacity in Yancheng, China. – Water Supply 21(6): 3099-3113.
[18] Du, P., Arndt, S. K., Farrell, C. (2019): Is plant survival on green roofs related to their drought response, water use or climate of origin? – Science of the Total Environment 667: 25-32.

[19] Duan, H., Xu, M., Cai, Y., Wang, X., Zhou, J., Zhang, Q. (2019): A holistic wetland ecological water replenishment scheme with consideration of seasonal effect. – Sustainability 11(3).
[20] Feng, C., Tang, X., Jin, Y., Guo, Y., Zhang, X. (2019): Regional energy-water nexus based on structural path betweenness: a case study of Shanxi Province, China. – Energy Policy 127: 102-112.
[21] Gallego-Ayala, J., Juizo, D. (2014): Integrating stakeholders' preferences into water resources management planning in the Incomati River Basin. – Water Resources Management 28(2): 527-540.
[22] Gao, C., Mei, Y., Lv, S., Wang, Y., Yuan, J. (2014): Assessment and prediction of water resources carrying capacity based on AHP-fuzzy method: a case study on Hanjiang River Basin. – Journal of Changjiang River Scientific Research Institute 31(09): 21-28.
[23] Gao, J., Gao, Q., Liu, Q., Yang, J. (2023): Factors influencing the regional diffusion of watershed ecological compensation policies: a case study of China. – Journal of Water Resources Planning and Management 149(11).
[24] Gibson, F. L., Tapsuwan, S., Walker, I., Randrema, E. (2015): Drivers of an urban community's acceptance of a large desalination scheme for drinking water. – Journal of Hydrology 528: 38-44.
[25] Gohil, J., Patel, J., Chopra, J., Chhaya, K., Taravia, J., Shah, M. (2021): Advent of Big Data technology in environment and water management sector. – Environmental Science and Pollution Research 28(45): 64084-64102.
[26] Griffith, D. A., Chun, Y. (2018): GIS and Spatial Statistics/Econometrics: An Overview. – In: Huang, B. (ed.) Comprehensive Geographic Information Systems. Elsevier, Oxford, pp. 1-26.
[27] Guo, L., Wang, Q. (2023): Simulation of population size and economic scale supportable by available freshwater in China in 2030. – Natural Resources Forum. https://doi.org/10.1111/1477-8947.12346.
[28] Han, A., Huang, J., Wang, X., Zhu, Z. (2023): Efficient water-saving irrigation, space efficiency and agricultural development - study based on spatial stochastic frontier model. – Journal of Systems Science & Complexity 36(6): 2559-2579.
[29] He, S., Luo, D., Guo, K. (2020): Evaluation of mineral resources carrying capacity based on the particle swarm optimization clustering algorithm. – Journal of the Southern African Institute of Mining and Metallurgy 120(12): 681-691.
[30] Hu, Q., He, X. (2018): An integrated approach to evaluate urban adaptive capacity to climate change. – Sustainability 10(4).
[31] Jiayu, P., Zheng, B., Chu, Z., Wang, X. (2020): Attaining sustainable water resource utilization in lake basins using progressive operational scenario analysis. – Water Resources Management 34(3): 887-904.
[32] Liu, C., Jiang, W., Liu, Y., Liu, Y. (2023): Evaluation for water and land resources system efficiency and influencing factors in China: a two-stage network DEA model. – Land 12(2).
[33] Liu, M., Zhang, J., Wang, C., Liu, H. (2019): Research on water resources carrying capacity of Changzhou City based on neural network. – Fresenius Environmental Bulletin 28(4): 2725-2732.
[34] Liu, X. Y., Peng, D. Y. (2020): Green efficiency of industrial water resource in China and its influencing factors: empirical evidence from China's 30 provinces. – Applied Ecology and Environmental Research 18(2): 3057-3072.
[35] Lu, W., Xu, C., Wu, J., Cheng, S. (2019): Ecological effect assessment based on the DPSIR model of a polluted urban river during restoration: a case study of the Nanfei River, China. – Ecological Indicators 96: 146-152.
[36] Lyu, S., Chen, W., Zhang, W., Fan, Y., Jiao, W. (2016): Wastewater reclamation and reuse in China: Opportunities and challenges. – Journal of Environmental Sciences 39: 86-96.

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DOI: http://dx.doi.org/10.15666/aeer/2205_43294349

[37] Meng, L., Liu, Y., Ma, W., Wang, Q., Mo, X., Jinming, T. (2022): Variable fuzzy evaluation model for water resources carrying capacity in the Tarim River Basin, China. – Water Supply 22(2): 1445-1458.
[38] Mikesell, R. F. (1995): The limits to growth: a reappraisal. – Resources Policy 21(2): 127-131.
[39] Mou, H., Liu, C. (1994): A preliminary study on the coordination between regional water resources and its new cities' setting up in China. – Acta Geographica Sinica 49(4): 338-344.
[40] Mou, S., Yan, J., Sha, J., Deng, S., Gao, Z., Ke, W., Li, S. (2020): A comprehensive evaluation model of regional water resource carrying capacity: model development and a case study in Baoding, China. – Water 12(9).
[41] Ovchinnikov, N. P., Zyryanov, I. V. (2023): Impact of increased water inflow on main drainage system efficiency in mine. – Journal of Mining Science 59(2): 342-347.
[42] Qi, S. Z., Luo, F. (2005): Water environmental degradation of the Heihe River Basin in arid northwestern China. – Environmental Monitoring and Assessment 108(1-3): 205-215.
[43] Rafiei, V., Nejadhashemi, A. P., Mushtaq, S., Bailey, R. T., An-Vo, D.-A. (2022): Groundwater-surface water interactions at wetland interface: advancement in catchment system modeling. – Environmental Modelling & Software 152: 105407.
[44] Ren, B., Zhang, Q., Ren, J., Ye, S., Yan, F. (2020): A novel hybrid approach for water resources carrying capacity assessment by integrating fuzzy comprehensive evaluation and analytical hierarchy process methods with the cloud model. – Water 12(11).
[45] Robele Gari, S., Newton, A., Icely, J. D. (2015): A review of the application and evolution of the DPSIR framework with an emphasis on coastal social-ecological systems. – Ocean & Coastal Management 103: 63-77.
[46] Schjonning, P., Van Den Akker, J. J. H., Keller, T., Greve, M. H., Lamande, M., Simojoki, A., Stettler, M., Arvidsson, J., Breuning-Madsen, H. (2015): Driver-Pressure-State-Impact-Response (DPSIR) Analysis and Risk Assessment for Soil Compaction-A European Perspective. – In: Sparks, D. L. (ed.) Advances in Agronomy. Vol 133. Academic Press, Burlington, pp. 183-237.
[47] Seah, H., Lee, N. (2020): Technological enablers and confidence building in end-users for effective non-domestic water demand management. – International Journal of Water Resources Development 36(6): 992-1013.
[48] Shah, F. A., Zilberman, D., Chakravorty, U. (1995): Technology adoption in the presence of an exhaustible resource - the case of groundwater extraction. – American Journal of Agricultural Economics 77(2): 291-299.
[49] Short, R. (1998): An essay on the principle of population. – Nature 395(6701): 456-456.
[50] Spearing, L. A., Tariq, M., Safarpour, H., Abia, T., Mallory, M., Guild, J., Katz, L. E., Faust, K. M. (2023): Moving beyond techno-economic considerations: incorporating organizational constraints into fit-for-use technologies. – Current Opinion in Chemical Engineering 42: 100950.
[51] Sun, M., Wang, J., He, K. (2020): Analysis on the urban land resources carrying capacity during urbanization - a case study of Chinese YRD. – Applied Geography 116: 102170.
[52] Sun, W., Zhang, Y., Chen, H., Zhu, L., Wang, Y. (2022): Trend analysis and obstacle factor of inter provincial water resources carrying capacity in China: from the perspective of decoupling pressure and support capacity. – Environmental Science and Pollution Research 29(21): 31551-31566.
[53] Swangjang, K., Kornpiphat, P. (2021): Does ecotourism in a Mangrove area at Klong Kone, Thailand, conform to sustainable tourism? A case study using SWOT and DPSIR. – Environment Development and Sustainability 23: 15960-15985.
[54] Swiader, M., Lin, D., Szewranski, S., Kazak, J. K., Iha, K., Van Hoof, J., Belcakova, I., Altiok, S. (2020): The application of ecological footprint and biocapacity for

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43294349

environmental carrying capacity assessment: A new approach for European cities. – Environmental Science & Policy 105: 56-74.
[55] Tatar, M., Papzan, A., Ahmadvand, M. (2022): Understanding factors that contribute to farmers' water conflict behavior. – Water Policy 24(4): 589-607.
[56] Wang, G., Xiao, C., Qi, Z., Liang, X., Meng, F., Sun, Y. (2021): Water resource carrying capacity based on water demand prediction in Chang-Ji economic circle. – Water 13(1).
[57] Wang, J., Xu, C. (2017): Geodetector: principle and prospective. – Acta Geographica Sinica 72(01): 116-134.
[58] Wang, Q., Li, S., Li, R. (2019): Evaluating water resource sustainability in Beijing, China: Combining PSR model and matter-element extension method. – Journal of Cleaner Production 206: 171-179.
[59] Wang, T., Jian, S., Wang, J., Yan, D. (2022): Dynamic interaction of water-economic-social-ecological environment complex system under the framework of water resources carrying capacity. – Journal of Cleaner Production 368: 133132.
[60] Wang, Z., Fu, X. (2023): Scheme simulation and predictive analysis of water environment carrying capacity in Shanxi Province based on system dynamics and DPSIR model. – Ecological Indicators 154: 110862.
[61] Wei, X., Wang, J., Wu, S., Xin, X., Wang, Z., Liu, W. (2019): Comprehensive evaluation model for water environment carrying capacity based on VPOSRM framework: A case study in Wuhan, China. – Sustainable Cities and Society 50: 101640.
[62] Wei, Z., Ji, D., Yang, L. (2023): Comprehensive evaluation of water resources carrying capacity in Henan Province based on entropy weight TOPSIS - coupling coordination - obstacle model. – Environmental Science and Pollution Research 30(54): 115820-115838.
[63] Yang, J. Y., Zhang, B., Wu, Y. F., Feng, Y. R., Zheng, Y., Shi, B. X. (2019a): Balance between construction and conservation: strategy in water sensitive area planning. – Applied Ecology and Environmental Research 17(4): 7283-7299.
[64] Yang, L., Wang, L. (2022): Comprehensive assessment of urban water resources carrying capacity based on basin unit: a case study of Qingdao, China. – Water Supply 22(2): 1347-1359.
[65] Yang, M. X., Zhang, Y., Wang, H., Jiang, Y. Z., Xu, Z., Lei, X. H. (2019b): prediction of Annual runoff at the Danjiangkou Reservoir, China based on forecast domain. – Applied Ecology and Environmental Research 17(4): 9561-9575.
[66] Ye, Q. (2020): Quality evaluation of ecological restoration of urban water pollution based on analytic hierarchy process. – Journal of Coastal Research 104(SI):10-13.
[67] Yu, X., Zhuge, Y., Li, G., Du, Q., Zhang, D., Tan, H., Zhang, S. (2018): A study of the ecological effects of water supplement conditions in Ebinur Lake. – Applied Ecology and Environmental Research 16(6): 7777-7790.
[68] Zhang, Y., Wei, Y., Mao, Y. (2023): Sustainability assessment of regional water resources in China Based on DPSIR model. – Sustainability 15(10).
[69] Zhao, Y., Wang, Y., Wang, Y. (2021): Comprehensive evaluation and influencing factors of urban agglomeration water resources carrying capacity. – Journal of Cleaner Production 288: 125097.
[70] Zheng, X. Y., Angelakis, A. N. (2018): Chinese and Greek ancient urban hydro-technologies: similarities and differences. – Water Science and Technology-Water Supply 18(6): 2208-2223.
[71] Zhi, X., Anfuding, G., Yang, G., Gong, P., Wang, C., Li, Y., Li, X., Li, P., Liu, C., Qiao, C., Gao, Y. (2022): Evaluation of the water resource carrying capacity on the north slope of the Tianshan Mountains, Northwest China. – Sustainability 14(3): 1905.
[72] Zhou, F., Zhang, W., Jiang, A., Peng, H., Li, L., Deng, L., Sun, Y., Wang, H. (2023): Spatial-temporal variation characteristics and coupling coordination of the "water resources - water environment - water ecology" carrying capacity in the Three Gorges Reservoir Area. – Ecological Indicators 154: 110874.

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