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Comprehensive Analysis of Coordination Relationship between Water Resources Environment and High-Quality Economic Development in Urban Agglomeration in the Middle Reaches of Yangtze River

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Abstract: Water resources environment and high-quality economic development both have crucial significance to sustainable development. To explore the nexus between them, an integrated evaluation system was firstly established in this study on the basis of their complicated synergy mechanism. Secondly, the index weights of urban agglomeration in the middle reaches of the Yangtze River from 2008 to 2017 were calculated by project pursuit-entropy weight method (PP-EWM) combined with an immune grey wolf optimizer algorithm (IGWO). Finally, the static and dynamic coordination degrees of 31 cities in the urban agglomeration were measured by membership function coordination model (MFCM), and the temporal and spatial characteristics of the coordination degrees were analyzed. The results showed that: (1) most cities in the urban agglomeration still had some room for improvement in terms of the water resources environment and high-quality economic development; (2) according to the changing characteristics of static coordination degrees, 31 cities were divided into five types, namely constantly rising type, constantly declining type, rising-declining type, declining-rising type and fluctuation type; (3) the dynamic coordination degrees demonstrated that the number of well coordinated cities decreased in recent years, and Xinyu and three provincial cities (i.e., Wuhan, Changsha and Nanchang) had poor performances. Overall, this study contributed to decision-making on synergic improvement between the water resources environment and high-quality economic development.

Keywords: water resources environment; high-quality economic development; comprehensive evaluation; coordination degree; project pursuit-entropy weight method; membership function coordination model

1. Introduction

Water resources are an indispensable resource for both the survival of mankind and socio-economic development. However, with the accelerated development of China's economy, the ecological environment, especially the water resources environment, has been faced with tremendous pressure resulting from pollution discharge and overexploitation, which may have become an important bottleneck in China's development [1]. To alleviate the contradiction between the ecological environment and socioeconomic development, high-quality economic development that places great emphasis on the balance between socioeconomic progress and environmental protection has been considered as a promising way for sustainable development [2]. As a matter of fact, the water resources environment and high-quality economic development have interactions with each other. On one hand, water conservation and sewage reduction can benefit from the financial and technical supports provided by high-quality economic development; on the other hand, the realization of high-quality economic development depends on relaxing water supply shortage, reducing water environmental pollution and increasing water utilization efficiency [3]. Therefore, to advance their synergetic improvement in the area of sustainable development, it is essential to evaluate and analyze their associated relationship scientifically and quantitatively.

In current studies, the complex interrelationship between the water resources environment and high-quality economic development has been discussed at different scales, in which high-quality economic development has mainly come to be viewed as economic growth, industry development and socio-economic progress. From the point of view of economic growth, Suinyuy et al. [4] examined the role of water resources consumption on economic growth in 38 sub-Saharan African (SSA) countries by adapting the transcendental logarithmic production model Ke et al. [5] constructed an integrated model by combining a multi-objective optimization model with input–output analysis to explore the tradeoffs between economic growth, water utilization and environmental protection, taking Ordos in China as an example Li et al. [6]. conducted the decoupling analysis between economic development and water resources utilization in Jiangxi and Hubei provinces. From the point of view of industry development, Zhang et al. [7] analyzed the relationship between industry improvement and water resources utilization and pointed out that the primary and secondary industries are more dependent on water resources than the tertiary industries, and appropriate reduction in the development of energy-intensive industries is an effective way to protect the water resources environment. Shi et al. [8] found that the optimization and transformation of industrial structure was favorable to the improvement of water use efficiency by input–output analysis, based on the data of the Northwest region of China. Hristov et al. [9] analyzed the nexus between water consumption and economic sectors in Macedonia and concluded that changes of production technology and specializations in the water intensive industries are needed to ease the pressure on water resources. From the perspective of socio-economic progress, Wang et al. [10] pointed out that the relationship between the water resources environment and socio-economic development showed S-shaped characteristics, as water resources utilization was the key factor that restricted the socio-economic system. Habibi et al. [11] analyzed the relationship between the allocation of water resources and employment in agriculture and industry sectors by optimization model and found that the allocation of water resources could lead to the maximization of created jobs. Dou et al. [12] developed a physically based hydro-economic model to demonstrate the interactions between the water-resource system and the socio-economic system and studied the maximum sustainable socio-economic scale of the Huaihe River basin.

Regarding the evaluation methodology of the water resources environment and high-quality economic development, it is common to construct an integrated system with an economic scale, economic structure, water condition and water consumption, etc. [13,14], and conduct a principal component analysis (PCA), analytic hierarchy process (AHP), project pursuit (PP) and an entropy weight method (EWM) etc., as the approaches to determine the index weights [15], in which the combination of PP and EWM is a scientific and practical method, because it not only reasonably and precisely reduces the dimension of panel data [16], but also objectively determines weights according to the data's quantitative relationships [17]. In the assessing model of the coordination degrees, the coupling coordination degree model (CCDM) has been demonstrated to be an effective analytical method. For instance, Tan et al. [18] employed the CCDM to analyze the coupling coordination degrees of the water resources environment and economic development in Jiangsu. Similarly, Xu et al. [19] calculated the coupling degrees, coordination degrees and coupling coordination degrees of water-use efficiency and economic development by CCDM.

To summarize, previous research has made a lot of attempts to study the interaction effects between the water resources environment and high-quality economic development, but most studies simply equated high-quality economic development with economic growth, industry improvement and socio-economic progress. Consequently, interactions among the factors that belong to the water resources environment system and high-quality economic development system have not properly been considered, and a comprehensive and direct evaluation system for their coordination relationship has not been provided, resulting in independent policies and guidance for the water resources environment and high-quality economic development instead of systematic and sustainable plans. In fact, high-quality economic development is a system consisting of many factors, including economic gain, social equity and scientific and technological innovation [20,21], which have internal connections and interactions with the ecological environment [22]. Therefore, to explore the coordination relationship between the water resources environment and high-quality economic development synthetically, an integrated and multi-level assessing index system involving the systematic characteristics of water resources and economic development wellbeing needs to be established.

Additionally, concerned with the calculation and analysis of the coordination degrees between the two systems, the membership function coordination model (MFCM) based on the vector autoregressive (VAR) model is more convenient to dynamically reflect the coordination relationship between the systems, as the current coordinated values measured by VAR are related to previous values of its own system and other system simultaneously [23]. Thus, it has been adopted in the field of coordination degree calculation. For example, Yao et al. [24] used the MFCM to describe the coordination between intensive land use and economic development in the Yangtze River Delta. Jiang [25] studied the coordination between the ratio of fiscal revenue to GDP and economic development in Anhui province of China by employing the MFCM.

As a whole, the main contributions of this article are as follows:

(1) The integrated evaluation index system composed of subsystems of the water resources environment and high-quality economic development was established based on their theoretical systematic mechanism.

(2) The project pursuit-entropy weight method (PP-EWM) combined with the immune grey wolf optimizer algorithm (IGWO) were conducted to determine the index weights.

(3) The spatial and temporal characteristics and regional differences of static and dynamic coordination degrees measured by the MFCM were identified and analyzed.

(4) A case study on the urban agglomeration in the middle reaches of Yangtze River was carried out to provide a reference for regional synergic improvement between the water resources environment and high-quality economic development.

The reminder of this paper is organized as follows: the theoretical synergy mechanism between the water resources environment and high-quality economic development is presented and explained, and an integrated evaluation index system is established in Section 2. Section 3 displays the procedures of the proposed methodology, including the PP-EWM with the IGWO and the MFCM. Section 4 exhibits the research area and the data source in detail. The comprehensive evaluation values of the water resources environment and high-quality economic development and static and dynamic coordination degrees are calculated and analyzed by the proposed methodology in Section 5. Finally, conclusions are given in Section 6.

2. Synergy Mechanism and Evaluation Index System

2.1. Synergy Mechanism between Water Resources Environment and High-Quality Economic Development

In the ecologic system and socio-economic system, synergy phenomena are commonplace. Synergy means that all the factors within the subsystems work together to influence each other, advance the subsystems to combine into an organic whole system and reach the overall development goal. The interaction effect eventually makes a systematic function larger than the simple sum of the individual subsystems; that is, synergy gives a result of one plus one that is greater than two [21]. Specifically, the synergy mechanism between the water resources environment and high-quality economic development can be interpreted as two segments: one is the effect of the water resources environment on high-quality economic development, and another is the effect of high-quality economic development on the water resources environment.

The influences of the water resources environment on high-quality economic development are shown as supporting and restricting. On one hand, as a basic resource for economic activities and mankind living, an ample water supply and a bettering water ecological system satisfy the growing water demands in related industries and living needs, benefit residents' health and life quality, stimulate labor productivity and enthusiasm [26] and thus form the basis of high-quality economic development. On the other hand, the deterioration of the water resources environment leads to frequent water disaster and water scarcity, which has negative effects on production activities and the living environment, and eventually constrains high-quality economic development.

High-quality economic development affects the water resources environment as well. Funds provided by economic development support water infrastructure construction; clean technology stemming from innovation improvement reduces pollution discharge, the water-saving industry advancements that benefit from industry structure optimization are expected to relieve the water resources pressure, and efficient water resources utilization and allocation brought by a rational income distribution system prevents water resources from overexploitation [27]. On the contrary, low-quality economic development that relies on resource-intensive industry and unreasonable resources allocation imposes a great pressure and grim challenge on water use and water protection, and eventually induces the deterioration of the water resources environment. The synergy mechanism between the water resources environment and high-quality economic development. can be described as in Figure 1.

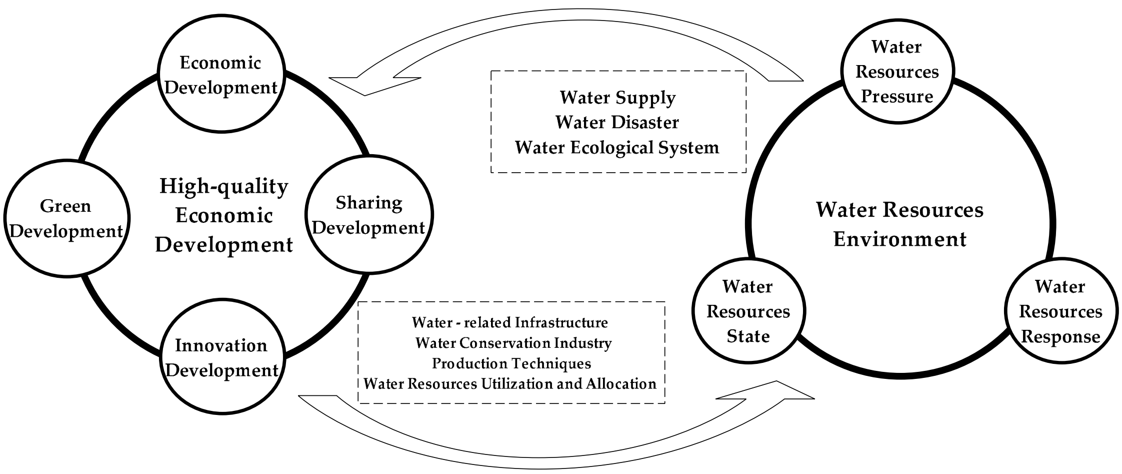

Figure 1. Synergy mechanism between the water resources environment and high-quality economic development.

2.2. Construction of the Evaluation Index System

The integrated system comprised of the water resources environment subsystems and the high-quality economic development subsystems (hereinafter referred to as WRES and HQEDS). Based on the PSR (pressure–state–response) model and data availability, the WRES is divided into 12 evaluation indicators within three aspects: water resources pressure, water resources state and water resources response (hereinafter referred to as WRP, WRS and WRR). For the HQEDS, 13 evaluation indicators were selected in terms of economic development, sharing development, innovation development and green development (hereinafter referred to as ED, SD, ID, and GD).

In the WRES, the 12 indicators within the three aspects were selected as follows:

1. WRP. Domestic water per capita for urban residents (X_1) and rural residents(X_2) that reflects water demands from urban and rural areas, separately; industrial wastewater discharge per GDP(X_3) was selected as the proxy for regional water pollution.

2. WRS. Here, four indicators were established, namely the total amount of water resources per capita (X_4), the precipitation per unit area(X_5), the underground water per unit area (X_6) and the surface water per unit area (X_7), which were selected to represent the water resources state.
3. WRR. The water consumption per GDP(X_8), the water consumption of industrial value added (X_9) and the water consumption of per mu farmland (X_{10}) were selected to measure the economic response of the water resources environment. Water supply per capita (X_{11}) is an indicator of the water supply response. Additionally, public green areas per capita (X_{12}) was selected as ecological environment response 17.

In HQEDS, the 13 indexes in four aspects are selected as follows:

1. ED. GDP per capita (X_{13}), the gross industrial output per capita(X_{14}), the proportion of tertiary industry GDP to gross GDP (X_{15}) and the total actual utilization of foreign capital per capita (X_{16}) reflect economic strength.
2. SD. The ultimate goal of high-quality economic development is to share development wellbeing with citizens, and thus sharing development is a key component of high-quality economic development. The average wages of employees (X_{17}) and the proportion of disposable income per capita to GDP per capita (X_{18}) were selected to present the income level; the proportion of disposable income between the urban and rural residents (X_{19}) reflects the urban–rural income distribution; registered urban unemployment rate (X_{20}) is a representative index of employment.
3. ID. The proportion of science and technology expenditure in government expenditure (X_{21}) and the growth rate of the value added of high-tech industries (X_{22}) were adopted as proxies of innovation level.
4. GD. The unit GDP energy-consuming parameter (X_{23}), the general comprehensive utilization of solid waste (X_{24}) and the urban garbage treatment rate (X_{25}) were used to measure ecological environment improvement.

Therefore, the integrated evaluation index system of the water resources environment and high-quality economic development is presented in Table 1.

Table 1. Integrated evaluation index system of the water resources environment and high-quality economic development.

Target Layer	First-Order Index	Second-Order Index	Third-Order Index	Direction	Weight
The integrated system of the water resources environment and high-quality economic development	Water resources environment subsystems (WRES)	Water resources pressure	Domestic water per capita for urban residents (X_1)	Negative	0.053
			Domestic water per capita for rural residents (X_2)	Negative	0.057
			Industrial waste water discharge per GDP (X_3)	Negative	0.068
		Water resources state	Total water resources per capita (X_4)	Positive	0.081
			Precipitation per unit area (X_5)	Positive	0.037
			Underground water per unit area (X_6)	Positive	0.276
			Surface water per unit area (X_7)	Positive	0.051
		Water resources response	Water consumption per 10,000 yuan of GDP (X_8)	Negative	0.049
			Water consumption of industrial value added (X_9)	Negative	0.067
			Water consumption of per mu farmland (X_{10})	Negative	0.049
			Water supply per capita (X_{11})	Positive	0.138
			Public green areas per capita (X_{12})	Positive	0.075
	High-quality economic development subsystems (HQEDS)	Economic development	GDP per capita (X_{13})	Positive	0.162
			Gross industrial output per capita (X_{14})	Positive	0.107
			The proportion of tertiary industry GDP to gross GDP (X_{15})	Positive	0.117
			Total actual utilization of foreign capital per capita (X_{16})	Positive	0.032
		Sharing development	Average wages of employees (X_{17})	Positive	0.045
			The proportion of disposable income per capita to GDP per capita (X_{18})	Positive	0.095
			The proportion of disposable income between urban and rural residents (X_{19})	Negative	0.090
			Registered urban unemployment rate (X_{20})	Negative	0.060
		Innovation development	The proportion of science and technology expenditure in government expenditure (X_{21})	Positive	0.029
			The growth rate of value added of high-tech industries (X_{22})	Positive	0.049
		Green development	Unit GDP energy-consuming parameter (X_{23})	Negative	0.126
			General comprehensive utilization of solid waste (X_{24})	Positive	0.022
			Sound urban garbage treatment rate (X_{25})	Positive	0.031

3. Methodology

3.1. Projection Pursuit-Entropy Weight Method

3.1.1. Projection Pursuit

We evaluated two subsystems based on the PP with the immune grey wolf optimizer (IGWO) algorithm. The model included the following steps.

Step 1: Normalization of Each Indicator

The extreme value normalization method was employed to unify each indicator value change range. When one indicator belongs to the benefit index (that is, the bigger the better), the normalization method is as follows:

$$x_{ij} = \frac{x'_{ij} - x_{j\text{-}min}}{x_{j\text{-}max} - x_{j\text{-}min}} \tag{1}$$

When one indicator belongs to the cost index (that is, the smaller the better), the normalization method is as follows:

$$x_{ij} = \frac{x_{j\text{-}max} - x'_{ij}}{x_{j\text{-}max} - x_{j\text{-}min}} \tag{2}$$

Assuming the sample set is $\left\{x_{ij}\middle|i = 1, 2, \cdots, n; j = 1, 2, \cdots, p\right\}$, x'_{ij} denotes the jth indicator value in ith sample set, and n and p represent the number of samples and indicators, respectively. $x_{j\text{-}max}$ and $x_{j\text{-}min}$ are the maximum and minimum values of the jth indicator, separately.

Step 2: Constructing the Projection Index Function

The PP puts p-dimensional data $\left\{x_{ij}\middle|j = 1, 2, \cdots, p\right\}$ integrated into a signal dimension projection value $z(i)$, with $a = (a_1, a_2, \cdots a_p)$ as the projection direction, in which a is the unit length vector. That is:

$$\sum_{j=1}^{p} a^2(j) = 1 \tag{3}$$

The projection value $z(i)$ is measured as follows:

$$z(i) = \sum_{j=1}^{p} a_j x_{ij} (i = 1, 2, \cdots, n) \tag{4}$$

The according sequence $z(i)$ can be classified using a one-dimensional scatter diagram of the projected values. The local projection point should be spread out as much as possible as a whole. On this basis, the projection indicator function can be constructed as:

$$Q(\alpha) = S_Z D_Z \tag{5}$$

where S_Z and D_Z denote the standard deviation and local density of $z(i)$.That is:

$$S_Z = \frac{\sum\limits_{i=1}^{n} (z(i) - \overline{z})^2}{n - 1} \tag{6}$$

$$D_z = \sum_{i=1}^{n} \sum_{j=1}^{p} (R - r_{ij}) \times u(R - r_{ij}) \tag{7}$$

where $\overline{z}$ is the mean value of the sequence $z(i)$ and R is the density window radius of D_z. The value of R should be large enough to allow, on average, a sufficient number of projection points in the window, to avoid making the moving average deviation too large, but it should not increase too fast with increasing n. A general value for R is 0.1 S_Z.The distance $r_{ij} = \left|z(i) - z(j)\right|$; and $u(t)$ is a unit speed function; when $t \geq 0$, its function value is 1, and when $t < 0$, its function value is 0.

Step 3: Optimizing the Projection Index Function

The optimal projection direction reflects different data structure features for the high-dimensional data. The optimal projection direction can be estimated by maximizing the projection index function:

$$\begin{cases} maxQ(\alpha) = S_Z \times D_Z \\ s.t. \sum_{j=1}^{p} a^2(j) = 1, a(j) \in [0,1] \end{cases} \quad (8)$$

The real coding based on the immune grey wolf optimizer algorithm (IGWO), whose basic frame is the grey wolf optimizer algorithm, was improved with the immune clonal method for better performance, and can simply and effectively solve the above problems via simulating the evolution process of the superior winning subjects in nature and chromosome exchange theory.

The principle of the IGWO and its implementation flow are as follows.

The IGWO, based on the grey wolf optimizer algorithm and the immune clonal theory, first performs the basic operation of the grey wolf optimizer algorithm (GWO): just as the process of encircling, hunting and attacking prey based on the alpha wolf, delta wolf and the omega wolf, is carried out with a simple structure, less control parameters and easy programming at first, and then the elite individuals are chosen for immune clone selection to improve the global convergence accuracy which improves the overall optimization ability. In this way, the projection direction of PP is encoded in the IGWO as the individual and after the encircling, hunting, attacking and immune clone selection operation, we get access to the optimal individual as the best projection direction for the PP. For the reader's convenience, the detailed computational process of the IGWO can be found in this paper [28]. Finally, the process of the IGWO to solve the best projection direction of PP is shown in Figure 2.

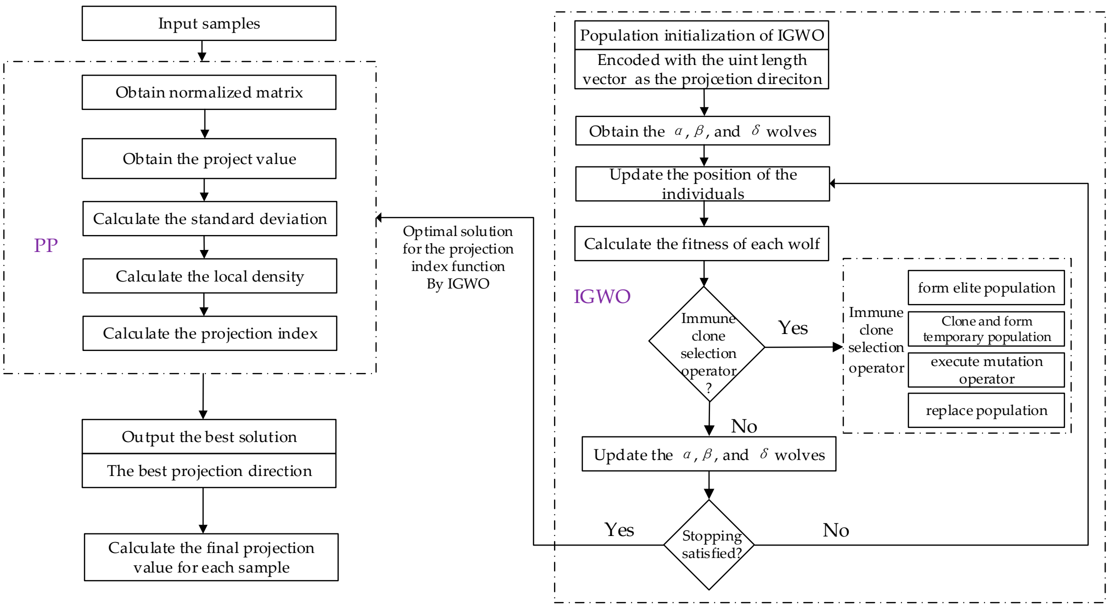

Figure 2. Principle of the immune grey wolf optimizer algorithm (IGWO) and its implementation flow.

3.1.2. Entropy Weight Method

Based on the values (z_{ij}) computed by PP, we employed the entropy weight method (EWM) to calculate the index weights. After we applied min–max normalization to transform the values, the calculation is as follow:

Step 1: calculate P_{ij}, the proportion of the jth evaluation index of the ith sample set:

$$P_{ij} = z_{ij} / \sum_{i=1}^{m} z_{ij} (0 \le P_{ij} \le 1) \quad (9)$$

Step 2: calculate e_j, the entropy of the jth evaluation index:

$$\begin{aligned} e_j &= -k\sum_{i=1}^{m} P_{ij} lnP_{ij} (e_j \geq 0) \\ k &= \tfrac{1}{lnm}(k > 0, m = 1, 2, \cdots 31) \end{aligned} \tag{10}$$

Step 3: calculate redundancy g_j:

$$g_j = 1 - e_j \tag{11}$$

Step 4: calculate the index weight of the various evaluation indices w_j:

$$w_j = \frac{g_j}{\sum\limits_{j=1}^{n} g_j}(n = 1, 2, \cdots, i) \tag{12}$$

Step5: calculate the comprehensive evaluation score U:

$$U = \sum_{i=1}^{n} y_{ij} w_j \times 100 \tag{13}$$

3.2. Membership Function Coordination Model

3.2.1. Static Membership Function Coordination Model

The calculation of static MFCM is as follows:

$$C_s(m, n) = \frac{min(U(m/n), U(n/m))}{max(U(m/n), U(n/m))}(0 \leq C_s(m, n) \leq 1) \tag{14}$$

where, $C_s(m, n)$ represents the static coordination degree between system m and system n. The larger the value of $C_s(m, n)$, the higher the coordination of the two systems; conversely, the lesser the value of $C_s(m, n)$, the lower the coordination of two systems. When the value of $C_s(m, n)$ is equal to 1, the two systems evolve synchronously. $U(m/n)$ represents the adaptability degree between system m and system n:

$$U(m/n) = exp(-(x - x')^2/s^2) \tag{15}$$

where x is the value of system n, s^2 is the mean square deviation, x' is the coordination degree of system m to system n, which can be calculated by the VAR model:

$$X_t = \alpha_{10} + \alpha_{11}X_{t-1} + \cdots + \alpha_{1p}X_{t-p} + b_{11}Y_{t-1} + \cdots + b_{1q}Y_{t-q} + \varepsilon_1 \tag{16}$$

$$Y_t = \alpha_{20} + \alpha_{21}X_{t-1} + \cdots + \alpha_{2p}X_{t-p} + b_{21}Y_{t-1} + \cdots + b_{2q}Y_{t-q} + \varepsilon_2 \tag{17}$$

where, X_t and Y_t denote the evaluation values of system m and system n in year t, respectively; X_{t-p} and Y_{t-q} represent the lagged evaluation values of system m in year $t - p$ and system n in year $t - q$, respectively. ε_1 and ε_2 are both white noise sequences. The lag order p and q are determined by the Akaike Information Criterion (AIC) minimum principle, namely, for equations of VAR model with different lag orders, the equation with minimum AIC value is selected.

3.2.2. Dynamic Membership Function Coordination Model

Since the values of the water resources environment and high-quality economic development are dynamic to some extent, the dynamic coordination degree should be considered as well. The dynamic coordination degree's added time variable based on the static one can reflect the changing trend between the systems, which is calculated as follows:

$$C_d(t) = \frac{1}{T}\sum_{t=0}^{T-1} C_s(m, n/t)(0 \le C_d(t) \le 1) \tag{18}$$

where, $C_d(t)$ represents the dynamic coordination degree between system m and system n in year t; $C_s(m, n/t)$ is the static coordination degree between system m and system n from $t - T + 1$ to t.

According to the study of Yao [24], we divided the coordination degrees between the water resources environment system and the high-quality economic development system into 10 types (Table 2).

Table 2. Coordination type between the WRES and the HQEDS.

Coordination Degree	Type	Coordination Degree	Type
0.90–1.00	Excellent coordination	0.40–0.49	Near disorder
0.80–0.89	Good coordination	0.30–0.39	Mild disorder
0.70–0.79	Medium coordination	0.20–0.29	Medium disorder
0.60–0.69	Primary coordination	0.10–0.19	Severe disorder
0.50–0.59	Eligible coordination	0.01–0.09	Extreme disorder

4. Study Area and Data Source

4.1. Introduction of Urban Agglomeration in the Middle Reaches of the Yangtze River

The urban agglomeration in the middle reaches of the Yangtze River, including 31 cities in the three provinces of Hubei, Hunan and Jiangxi, which are located in the middle areas of China, is an oversized urban agglomeration composed of the Wuhan urban agglomeration, the Chang-Zhu-Tan urban agglomeration and the urban agglomeration around the Poyang Lake areas (Figure 3) [29]. By the end of 2017, the area of urban agglomeration of the middle reach in the Yangtze River has reached 326,100 km^2, the permanent population is 125 million and the GDP is 7900 billion yuan. That is, the urban agglomeration accounts for 9.6% of China's economic output by 3.4% of the country's land area and 9.0% of the entire population.

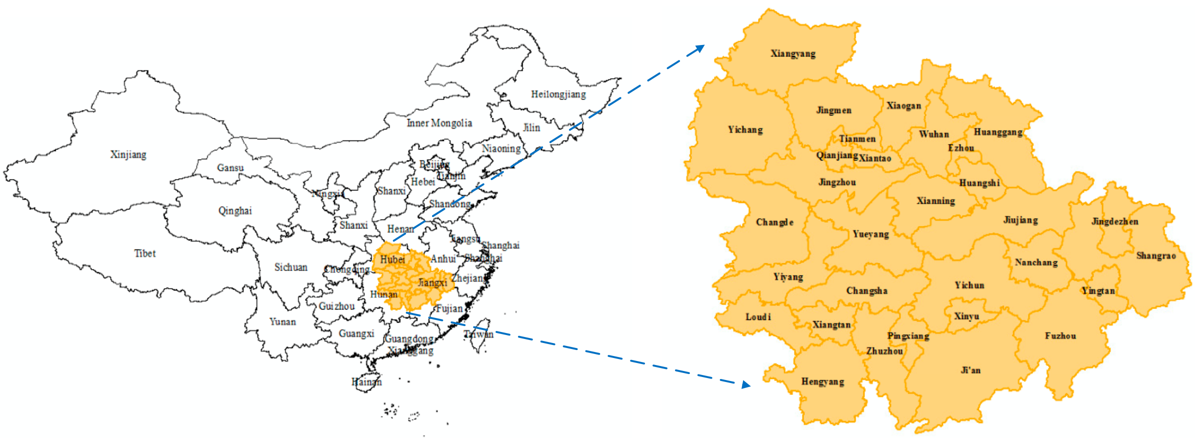

Figure 3. Location of the urban agglomeration in the middle reaches of the Yangtze River in China.

The urban agglomeration in the middle reaches of the Yangtze River is famous for its abundant water resources, where Poyang Lake, Dongting Lake, the Han River, the Qingjiang River and many other rivers and lakes are located. Besides, the urban agglomeration has been one of the most promising regions in China for its hinterland location, transportation, industrial basis and talent reserve. As one of the core urban agglomerations of the Central Rise Strategy and the Yangtze River Economic Belt Strategy, the water resources environment and high-quality economic development of the urban agglomeration are continually attracting special attention. Existing studies have pointed out that the development quality of the regional ecosystem is relatively weak, which has become an important obstacle constraining high-quality economic development [30,31]. Following the aforementioned reasons, we selected the urban agglomeration in the middle reaches of the Yangtze River as the sample to conduct a coordination analysis between the water resources environment and high-quality economic development. The sample in this study was the panel data based on 31 cities as a cross-section, which were comprise of 13 cities of the Wuhan urban agglomeration, eight cities of the Chang-Zhu-Tan urban agglomeration and 10 cities of the urban agglomeration around the Poyang Lake areas.

4.2. Data Source

In this study, the data was mainly from the following resources: China City Statistical Yearbook (2007–2018), Jiangxi Statistical Yearbook (2007–2018), Hubei Statistical Yearbook (2007–2018), Hunan Statistical Yearbook (2007–2018) and the bulletins of water resources of the Jiangxi, Hubei and Hunan provinces. Some lacking data of individual years have been calculated by geometric average method to maintain data integrity.

In the year 2008, the Wuhan urban agglomeration in the Hubei province and the Chang-Zhu-Tan urban agglomeration in the Hunan province were officially authorized as the pilot areas for the comprehensive reform of building a resource-conserving and environment-friendly society, which became a strategic fulcrum for the "Central Rise Strategy", and marked that the urban agglomeration in the middle reaches of Yangtze River had formed a preliminary system as well. The most recent year that the national and provincial Bureau of Statistics has provided data for is 2017, thus we selected 2008 and 2017 as the starting and ending year in this study.

5. Results and Discussion

5.1. Comprehensive Evaluation of WRES and HQEDS

The weights of the 25 indicators in the two systems (i.e., the WRES and the HQEDS) were determined by PP-EWM, as shown in Table 1.

With Equation (13), the average comprehensive evaluation values of the WRES and the HQEDS of each city from 2008 to 2017 were obtained and are presented in Figures 4 and 5, respectively.

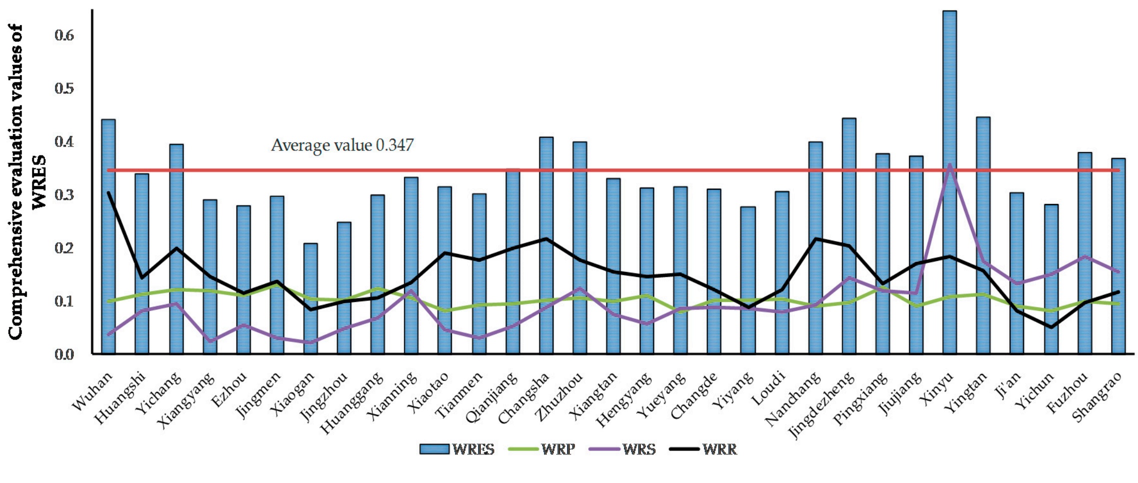

Figure 4. Average comprehensive evaluation values of the WRES from 2008 to 2017.

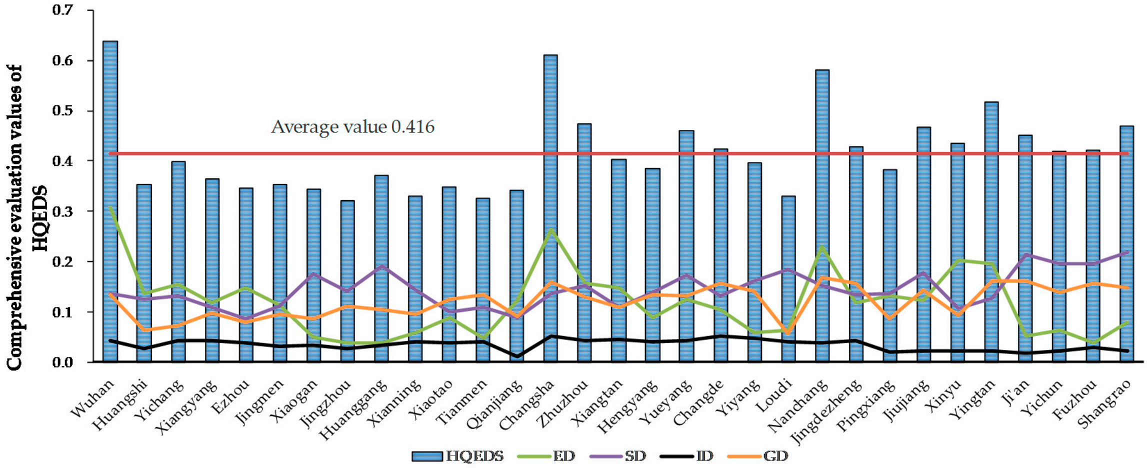

Figure 5. Average comprehensive evaluation values of the HQEDS from 2008 to 2017.

In Figure 4, from 2008 to 2017, the average comprehensive evaluation value of the WRES was 0.347; Xinyu had the highest value and Xiaogan had the lowest. A total of 13 areas (Wuhan, Yichang, Qianjiang, Changsha, Zhuzhou, Nangchang, Jingdezhen, Pingxiang, Jiujiang, Xinyu, Yingtan, Fuzhou and Shangrao), accounting for 41.9% of the total, had WRES values over the average value. Specifically, eight cities located in the urban agglomeration around Poyang Lake had higher comprehensive evaluation values of the WRES than the average, and the main reason lied in the higher WRS scores when compared with other cities. Wuhan, Yichang and Qianjiang, located in the Wuhan urban agglomeration, had comprehensive evaluation values over average value mostly because of their outstanding performance in WRR. The main reason that the two cities located in the Chang-Zhu-Tan urban agglomeration (Changsha and Zhuzhou) had above-average evaluation values of WRES could be ascribed to their high scores in WRR.

Moreover, in Figure 5, from 2008 to 2017, the average comprehensive evaluation value of the HQEDS reached 0.416 which was slightly higher than the average value of the WRES; Wuhan had the highest value and Jingzhou had the lowest. A total of 14 areas (Wuhan, Changsha, Zhuzhou, Yueyang Changde, Nanchang, Jingdezhen, Jiujiang, Xinyu, Yingtan, Ji'an, Yichun, Fuzhou and Shangrao), accounting for 45.2% of the total, had HQEDS values over the average value. Specifically, the comprehensive evaluation scores of the HQEDS in the urban agglomeration around Poyang Lake were all above the average value except for Pingxiang, generally benefiting from high values in GD, which implied that the cities in the region had a well balanced high-quality economic development. By contrast, in the Wuhan urban agglomeration, only Wuhan exceeded the average score, implying that the cities' high-quality economic development was extremely unbalanced. The scores of the HQEDS for Changsha, Zhuzhou, Yueyang and Changde, that are located in Chang-Zhu-Tan urban agglomeration, were over the average value, of which Changsha's score was the highest. For the region as a whole, the Chang-Zhu-Tan urban agglomeration had a more prominent achievement in ID values.

Overall, from 2008 to 2017, the comprehensive evaluation values of the WRES and the HQEDS were relatively low, and more than half of the cities' scores had below-average values, which suggested that the urban agglomeration still had lots of room for improvement in terms of the water resources environment as well as high-quality economic development.

5.2. Analysis of Static Coordination Degree

The VAR model is the preparation step of the analysis of the MFCM, and thus the lag orders of the variables should be determined by AIC minimum principle at first, indicating that the equation of VAR model with the minimum AIC value should be selected, as shown in Table 3.

Table 3. Determination of the lag order of the vector autoregressive (VAR) model.

Lag Order	AIC Value	R-Squared	
		Water Resources Environment	High-Quality Economic Development
1	−7.2078	0.6116	0.7377
2	−5.8612	0.8024	0.7647
3	−1.2724	0.8224	0.7626
4	−5.4856	0.8251	0.7638
5	−2.1888	0.8209	0.7648

In Table 3, comparing the equations of VAR model with different lag orders, the equation with first-order lag has the minimum AIC value; and the R-squared values of the equation are 0.6116 and 0.7377 when the water resources environment and high-quality economic development are taken as the dependent variables, separately, implying their good fitting characteristics. Thereby, according to the AIC minimum principle, the coordination degrees of the water resources environment and high-quality economic development from 2008 to 2017 can be calculated by the VAR model on the premise of the first-order lag of their own values. The calculation results are as follows:

$$X_t = 0.0986 \times X_{t-1} - 0.0763 \times Y_{t-1} \quad (19)$$

$$Y_t = 0.0449 \times X_{t-1} + 0.0839 \times Y_{t-1} \quad (20)$$

Then, we obtained the evaluation values of the WRES and the HQEDS from 2008 to 2017 by putting their evaluation values from 2007 to 2016 into the above two equations, respectively. Lastly, Equation (15) was used to calculate the adaptability degrees of the two systems, and, according to Equation (14), the static coordination degrees could be measured. The results are presented in Table 4.

Based on Table 4, the cities' static coordination degrees between the WRES and the HQEDS exhibited large differences. To analyze the regionalization characteristics of the static coordination degrees, we divided the 31 cities into five types, according to their coordination degrees from 2008 to 2017, namely the constantly rising type, the constantly declining type, the rising-declining type, the declining-rising type and the fluctuation type.

The constantly rising type included five cities. From 2008 to 2017, the coordination degrees of Huangang, Xiantao, Yiyang, Nanchang and Jingdezhen increased from 0.280, 0.555, 0.379, 0.177 and 0.558 to 0.559, 0.974, 0.845 0.596 and 0.747, corresponding to eligible coordination, excellent coordination, near disorder, eligible coordination and medium coordination, respectively.

Jiujiang belonged to the constantly decreasing type. In 2008, Jiujiang's coordination degree was 0.841, however, in 2017, it decreased to 0.511, corresponding to eligible coordination.

The rising-declining type contained 16 cities, in which the coordination degrees of Huangshi, Jingmen, Xianning, Qianjiang, Hengyang, Changde and Loudi all climbed over 0.90 in 2013, but their degrees continuously declined since then. In 2017, the coordination degrees of Xianning and Hengyang slightly decreased to 0.917 and 0.861, indicating excellent coordination and good coordination, separately. The coordination degrees of Jingmen and Changde declined to 0.724 and 0.739, respectively, changing to medium coordination. Qianjiang' coordination degree dropped to 0.561, indicating eligible coordination; and the coordination degrees of Huangshi and Loudi drastically dropped to 0.492 and 0.488, respectively, turning to near disorder. Tianmen and Zhuzhou approached excellent coordination in 2011, but both fell sharply to 0.556 and 0.374 in 2017, demoting to eligible coordination and mild disorder, respectively. The coordination degrees of Yichang, Xiangtan and Shangrao significantly dipped from their peaks in 2010 to 0.568, 0.239 and 0.333 in 2017, demonstrating eligible coordination, medium disorder and mild disorder, respectively. The coordination degrees of Fuzhou, Yichun, Pingxiang and Yingtan reached their top degrees in 2009, 2011, 2012 and 2014, respectively. However, in 2017, their coordination degrees sharply dropped to 0.590, 0.568, 0.487 and 0.157, the first two being eligible coordination and the latter two individually turning to near disorder and severe disorder.

Table 4. Static coordination degrees of the WRES and the HQEDS of the urban agglomeration in the middle reaches of Yangtze River.

Region	City	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Wuhan urban agglomeration	Wuhan	0.170	0.247	0.364	0.328	0.169	0.278	0.151	0.128	0.209	0.177
	Huangshi	0.842	0.868	0.869	0.625	0.750	0.982	0.947	0.810	0.889	0.492
	Yichang	0.645	0.765	0.870	0.583	0.517	0.709	0.604	0.745	0.753	0.583
	Xiangyang	0.710	0.704	0.677	0.800	0.529	0.754	0.653	0.836	0.723	0.805
	Ezhou	0.844	0.744	0.961	0.852	0.602	0.490	0.731	0.743	0.769	0.820
	Jingmen	0.872	0.679	0.695	0.926	0.496	0.980	0.687	0.802	0.907	0.724
	Xiaogan	0.579	0.542	0.666	0.604	0.339	0.634	0.514	0.645	0.724	0.448
	Jingzhou	0.560	0.668	0.889	0.796	0.553	0.939	0.591	0.916	0.730	0.984
	Huanggang	0.280	0.543	0.725	0.971	0.483	0.879	0.649	0.926	0.909	0.559
	Xianning	0.833	0.904	0.757	0.703	0.749	0.934	0.673	0.688	0.647	0.917
	Xiaotao	0.555	0.957	0.947	0.910	0.585	0.952	0.974	0.682	0.852	0.974
	Tianmen	0.954	0.877	0.913	0.999	0.729	0.838	0.875	0.754	0.961	0.556
	Qianjiang	0.845	0.839	0.715	0.912	0.812	0.962	0.780	0.697	0.716	0.516
Chang-Zhu-Tan urban agglomeration	Changsha	0.112	0.213	0.285	0.210	0.349	0.309	0.228	0.052	0.114	0.420
	Zhuzhou	0.514	0.362	0.820	0.928	0.584	0.994	0.827	0.355	0.609	0.374
	Xiangtan	0.418	0.569	0.784	0.615	0.536	0.725	0.538	0.505	0.772	0.239
	Hengyang	0.598	0.337	0.862	0.750	0.671	0.986	0.914	0.767	0.655	0.861
	Yueyang	0.376	0.492	0.787	0.353	0.297	0.591	0.478	0.323	0.244	0.659
	Changde	0.415	0.557	0.741	0.806	0.499	0.961	0.514	0.241	0.429	0.739
	Yiyang	0.379	0.396	0.603	0.575	0.453	0.952	0.501	0.499	0.684	0.845
	Loudi	0.872	0.555	0.778	0.928	0.816	0.981	0.894	0.918	0.798	0.488
Urban agglomeration around Poyang Lake	Nanchang	0.177	0.249	0.376	0.337	0.208	0.146	0.309	0.235	0.205	0.596
	Jingdezheng	0.558	0.557	0.500	0.824	0.657	0.819	0.923	0.809	0.933	0.747
	Pingxiang	0.838	0.547	0.812	0.678	0.962	0.939	0.948	0.522	0.677	0.487
	Jiujiang	0.841	0.836	0.536	0.824	0.407	0.489	0.427	0.178	0.559	0.511
	Xinyu	0.104	0.060	0.068	0.233	0.101	0.108	0.096	0.140	0.128	0.109
	Yingtan	0.610	0.689	0.779	0.768	0.711	0.664	0.964	0.215	0.316	0.157
	Ji'an	0.477	0.335	0.408	0.469	0.412	0.488	0.293	0.557	0.283	0.885
	Yichun	0.541	0.748	0.837	0.964	0.657	0.439	0.156	0.181	0.424	0.568
	Fuzhou	0.777	0.961	0.625	0.684	0.794	0.726	0.590	0.709	0.930	0.590
	Shangrao	0.788	0.223	0.878	0.534	0.582	0.409	0.456	0.713	0.248	0.333

The declining-rising type included five cities. The coordination degrees of Xiangyang and Jingzhou both dropped to their respective lowest points in 2012, but then rebounded to 0.805 and 0.984, demonstrating good coordination and excellent coordination, respectively. The coordination degrees of Changsha rapidly increased over 0.420, indicating near disorder, after reaching its lowest in 2015. Yueyang and Ji'an both hit the lowest points of their coordination degrees in 2016, but their degrees rapidly increased to their peaks in 2017, promoting their primary coordination and good coordination, respectively.

The fluctuation contained four cities, including Wuhan, Ezhou, Yueyang and Xinyu. From 2008 to 2017, the coordination degrees for Wuhan and Ezhou underwent the fluctuation of "rising-falling -rising-falling" with a "M-shaped" characteristic, displaying severe disorder and good coordination in 2017, respectively; by contrast, Xinyu's coordination degrees experienced the wave of "falling-rising-falling-rising" with a "W-shaped" characteristic, indicating severe disorder. Yueyang's coordination degrees presented the "N-shaped" characteristic of "rising-falling-rising", corresponding to good coordination in 2017.

5.3. Analysis of Dynamic Coordination Degree

The dynamic coordination degrees can be applied to further reveal the development trend of the coordination between the two systems, which was calculated by Equation (18). Combined with Table 2, the distribution graphs of the dynamic coordination degrees in 2008, 2011, 2014 and 2017 were drawn by ArcGIS10.2 (Figure 6). From the four graphs and the evaluation scores of the WRES and the HQEDS, three points can be concluded:

1. From temporal characteristics, the number of cities in which the coordination type was retained in good coordination and above ($C_d > 0.8$) varied with time. Specifically, in 2008, the number of cities that had a coordination degree that was in good coordination and above was nine, and the cities' average coordination degree was 0.860. In 2011, the number decreased to five, and the average coordination degree slightly dropped to 0.852. In 2014, the number increased to nine again and the average coordination degree remained at 0.852. However, in 2017, the number sharply fell to three and the average declined to 0.830. This signified that the superior coordination relationship between the WRES and the HQEDS in the urban agglomeration tended to be unstable during the study period. Combined with the evaluation values of the two subsystems, it was the unsynchronized improvement of the WRES and the HQEDS that resulted in the sharp decline of the quantity of well coordinated cities. From 2014, high-quality economic development had accelerated, but the water resources environment sluggishly improved and even invariably stagnated. Therefore, for the urban agglomeration in the middle reaches of Yangtze river, the key direction to promote the coordinated relationship between the WRES and the HQEDS lies in the improvement of the water resources environment by taking advantage of high-quality economic achievement.
2. From spatial characteristics, the coordination degrees of Xinyu and the three provincial cities (i.e., Wuhan, Changsha and Nanchang) were continuously in a poor level. For the four cities, the reasons that caused the severe imbalance between the WRES and the HQEDS were different. Specifically, Xinyu had the top average scores for the WRES out of all cities because of its advantageous water resources condition, but it failed to translate the favorable natural condition into the driving force for high-quality economic development, which is, for Xinyu, reasonable water utilization to enhance economic benefit. As the three center cities in the urban agglomeration, Wuhan, Changsha and Nanchang, taking priority in the high-quality economic development, it was urgent to convert the advantages from high-quality economic development into impetus to improve the water resources environment, such as the upgrading of water-related infrastructure, the promotion of pollution-reducing technologies and the supporting of water conservation industries.
3. The nature of the coordination may have significantly varied among regions with the same coordination type. Although the dynamic coordination degrees of Xiangyang and Fuzhou remained in the range of (0.60–0.80), the evaluation scores for the WRES and the HQEDS in Fuzhou were both higher than the overall average scores (its average scores for the WRES and the HQEDS were 0.379 and 0.420, respectively), thus its coordination should be defined as high-high coordination. However, the evaluation scores for the WRES and the HQEDS of Xiangyang were both below the overall average values (its average scores for the WRES and the HQEDS were 0.290 and 0.364, respectively), and its coordination should be defined as low-low coordination. Therefore, in order to identify the differences among the cities with the same coordination type in detail, the comprehensive values of the WRES and the HQEDS must be considered.

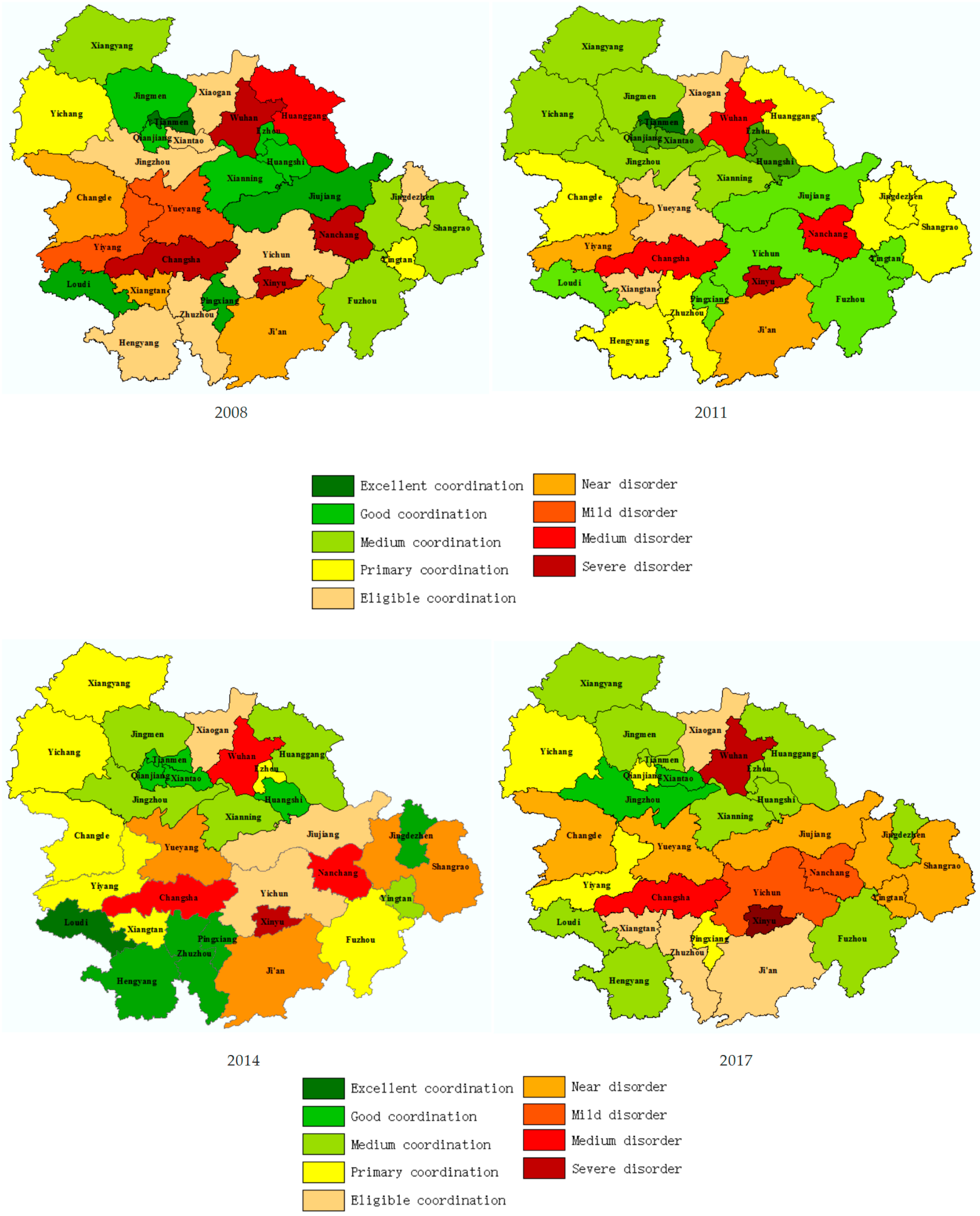

Figure 6. Spatial distribution of the dynamic coordination degree between the WRES and the HQEDS of the urban agglomeration in the middle reaches of the Yangtze River.

6. Conclusions

In this study, the comprehensive evaluation values of the WRES and the HQEDS of the urban agglomeration in the middle reaches of the Yangtze River from 2008 to 2017 were measured by PP-EWM with the IGWO, and the coordination degrees of the two subsystems were analyzed by MFCM. The calculation and discussion led to the following conclusions:

(1) Based on the synergetic mechanism between the water resources environment and high-quality economic development, the WRES were divided into water resources pressure, water resources state and water resources response; whereas the HQEDS was composed of economic development, sharing development, innovation development and green development.

(2) Comparing the evaluation values of the WRES and the HQEDS of the three urban agglomerations from 2008 to 2017, the Wuhan urban agglomeration had higher scores for

water resources response and economic development; the Chang-Zhu-Tan urban agglomeration had a prominent performance in water resources response and innovation development; and the urban agglomeration around Poyang Lake had advantages in water resources state and green development.

(3) According to the comprehensive evaluation values of the WRES and the HQEDS, less than half of the cities of the urban agglomeration in the middle reaches of the Yangtze River had evaluation values that exceeded the overall average values, and thus the cities in the urban agglomeration still had lots of room for improvement in terms of the water resources environment and high-quality economic development.

(4) The analysis of the static coordination degrees measured by the MFCM suggested that there were significant regional differences in the coordination degrees between the WRES and the HQEDS. According to the static coordination degrees, 31 cities in the urban agglomeration were divided into five types, namely the constantly rising type, the constantly declining type, the rising-declining type, the declining-rising type and the fluctuation type.

(5) The analysis of the dynamic coordination degrees calculated by the MFCM demonstrated that, in the study period, the cities that kept in good coordination and above decreased sharply in recent years, and Xinyu and the three provincial cities (i.e., Wuhan, Changsha and Nanchang) constantly had poor performances. Therefore, effective and scientific approaches that can promote the mutual conversion of advantages and achievements between the water resources environment and high-quality economic development should be raised and applied, in combination with practical solutions.

Several limitations to our findings deserve mentioning. Firstly, although PP-EWM combined with the IGWO was conducted in this study to calculate the index weights, more methods can be employed to optimize the weights calculation. Secondly, due to the complications of the evaluations of the WRES and the HQEDS, the integrated coordination evaluation system, which contained 25 indexes in this paper, may not fully reflect the connotation of the water resources environment and high-quality economic development. Thus, a more scientific and reasonable evaluation system should be under further consideration. Thirdly, the empirical results of this paper lack a comparative analysis with additional regions with similar or different water resource conditions and socio-economic development levels. Therefore, an investigation among different urban agglomerations should be compared for our in-depth joint assessment of the water resources environment and high-quality economic development in future research.

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References

1. Karaouzas, I.; Smeti, E.; Vourka, A.; Vardakas, L.; Mentzafou, A.; Tornés, E.; Sabater, S.; Muñoz, I.; Skoulikidis, N.T.; Kalogianni, E. Assessing the ecological effects of water stress and pollution in a temporary River-Implications for water management. *Sci. Total Environ.* **2018**, *618*, 1591–1604. [CrossRef] [PubMed]
2. Fang, D.C.; Ma, W.B. Study on the measurement of China's inter-provincial high-quality development and its spatial-temporal characteristics. *Reg. Econ. Rev.* **2019**, *2*, 61–70. (In Chinese)
3. Wang, G.Y.; Liu, J. Coordinating Evaluation of Water Resources Environment and Economic Development Based on Improved Water Ecological Footprint: A Case Study of Central Plains Urban Agglomeration. *Resour. Environ. Yangtze Basin* **2019**, *28*, 80–90. (In Chinese)

4. Suinyuy, D.N.; Xiong, Z.X.; Presley, K. Signatures of water resources consumption on sustainable economic growth in Sub-Saharan African countries. *Int. J. Sustain. Built Environ.* **2016**, *5*, 114–122. [CrossRef]
5. Ke, W.L.; Sha, J.H.; Yan, J.J.; Zhang, G.F.; Wu, R.R. A multi-objective input–output linear model for water supply, economic growth and environmental planning in resource-based cities. *Sustainability* **2016**, *8*, 160. [CrossRef]
6. Li, N.; Zhang, J.Q.; Wang, L. Decoupling and water footprint analysis of the coordinated development between water utilization and the economy in urban agglomeration in the middle reaches of the Yangtze River. *China Popul. Resour. Environ.* **2017**, *27*, 202–208. (In Chinese)
7. Zhang, X.J.; Dong, Z.C.; Luo, B.M. Industrial Structure Optimization based on Water Quantity and Quality Restrictions. *J. Hydrol. Eng.* **2013**, *18*, 1107–1113. [CrossRef]
8. Shi, Q.L.; Chen, S.Y.; Shi, C.C. The Impact of industrial transformation on water use efficiency in northwest region of China. *Sustainability* **2014**, *7*, 56–74. [CrossRef]
9. Hristov, J.; Martinovska-Stojcheska, A.; Surry, Y. The economic role of water in FYR Macedonia: An input-output analysis and implications for the Western Balkan countries. *Water Econ. Policy* **2016**, *2*, 1650025. [CrossRef]
10. Wang, J.J.; Guo, M.C.; Jiang, Z.D. The construction and application of an agricultural ecological-economic system coupling process model. *Acta Ecol. Sin.* **2010**, *30*, 2371–2378. (In Chinese)
11. Davijani, M.; Habibi nihabib, M.E.; Anvar, A. Nadjafzadeh. Multi-objective optimization model for the allocation of water resources in arid regions: Based on the maximization of socioeconomic efficiency. *J. Hydrol.* **2016**, *30*, 927–946. [CrossRef]
12. Dou, M.; Zuo, Q.T.; Ma, J.X. Simulation and control of the linked systems of water quantity-water quality-socio-economics in the Huaihe River basin. *Hydrol. Sci. J.* **2016**, *61*, 763–774. [CrossRef]
13. Qi, J. Fiscal expenditure incentives, spatial correlation and quality of economic growth: Evidence from a Chinese province. *Int. J. Bus. Manag.* **2016**, *11*, 191–201. (In Chinese) [CrossRef]
14. Wei, M.; Li, S.H. Study on the measurement of economic high-quality development level in Chinese in the New Era. *J. Quant. Tech. Econ.* **2018**, *35*, 3–20. (In Chinese)
15. Zhang, W.G.; Du, X.Z.; Huang, A.Q.; Yin, H.J. Analysis and comprehensive evaluation of water use efficiency in China. *Water* **2019**, *11*, 2620. [CrossRef]
16. Gao, Y.Y.; Xu, X.Y.; Wang, H.R.; Gao, X.; Yin, X.L. New model for water use efficiency evaluation of China and its application. *Syst. Eng. Theory Pract.* **2013**, *33*, 776–784. (In Chinese)
17. Yan, X.X.; Fan, L.; Fan, Y.Y. Spatial and temporal distribution and evolution of ecological-disaster-social system in China. *Macroecon. Res.* **2019**, *8*, 115–127. (In Chinese) [CrossRef]
18. Tan, F.; Shi, Y.Y. Coupling coordination degree evaluation between water resources environment and economic development: A case study in Jiangsu province. *J. Econ. Water Resour.* **2019**, *37*, 8–12. (In Chinese)
19. Xu, W.J.; Zhang, X.P.; Xu, Q.; Gong, H.L.; Li, Q.; Liu, B.; Zhang, J.W. Study on the coupling coordination relationship between water-use efficiency and economic development. *Sustainability* **2020**, *12*, 1246. [CrossRef]
20. Li, M.X.; Ren, B.P. Comprehensive Evaluation and Path Choice of China's High-Quality Development in the New Era. *Financ. Sci.* **2018**, *5*, 26–40. (In Chinese)
21. Li, Z.D.; Yang, W.P.; Wang, C.J.; Zhang, Y.S.; Yuan, X.L. Guided high-quality development, resources, and environmental forcing in China's green development. *Sustainability* **2019**, *11*, 1936. [CrossRef]
22. Wang, Y.B.; Lu, Y.; Wang, W.H. New research progress on the coordinated coupling of high-quality economic development and ecological environmental protection. *J. Beijing Univ. Technol. (Soc. Sci. Ed.)* **2019**, *19*, 84–94. (In Chinese)
23. Zong, G.; Guo, C. Coordination evaluation of urban traffic accessibility and urban spatial structure system in Beijing. *Urban Probl.* **2014**, *5*, 49–54. (In Chinese) [CrossRef]
24. Yao, C.S.; Li, X.T.; Du, H. Coordination between land intensive use and economic development in Yangtze River Delta. *Econ. Geogr.* **2016**, *36*, 161–168. (In Chinese)
25. Jiang, L.Y. Study on the appropriate ratio of the Anhui fiscal revenue to GDP-Based on empirical analysis by Fuzzy Membership Function Model. *J. Chongqing Univ. Arts and Sci. (Soc. Sci. Ed.)* **2018**, *37*, 124–131. (In Chinese)
26. Albertini, E. Does Environmental Management Improve Financial Performance? A Meta-Analytical Review. *Organ. Environ.* **2013**, *26*, 431–457. [CrossRef]

27. Golley, J.; Meng, X. Income Inequality and Carbon Dioxide Emissions: The Case of Chinese Urban Households. *Energy Econ.* **2012**, *34*, 1864–1872. [CrossRef]
28. Zou, Q.; Liao, L.; Ding, Y. Flood Classification Based on a Fuzzy Clustering Iteration Model with Combined Weight and an Immune Grey Wolf Optimizer Algorithm. *Water* **2019**, *11*, 80. [CrossRef]
29. Html. NDRC. The Notice about the Development Plan of the Urban Agglomeration in the Middle Reaches of Yangtze River[R/OL]. Available online: http://www.sdpc.gov.cn/zcfb/zcfbtz/201504/t20150416_688229 (accessed on 13 April 2015).
30. Ma, J.; Li, X.F.; Zhang, H. The coordination of urban development quality system in urban agglomeration in the middle reaches of the Yangtze River. *Econ. Geogr.* **2016**, *36*, 53–61. (In Chinese)
31. Xie, S.; Deng, H.B. Quality evaluation of urban agglomeration development in the middle reaches of the Yangtze River. *Stat. Decis.* **2018**, *34*, 55–58. (In Chinese)

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