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Agricultural Water Use Efficiency - Economic Development - Ecological Environment in the Yangtze River Economic Belt Coordinated Development Study

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Abstract

This paper This paper takes 11 provinces and cities in China's Yangtze River Economic Belt as the research object, and analyzes them using the CRITIC-entropy weight combination weighting method, coupled coordination state and obstacle factors. It aims to explore how to promote the harmonious symbiosis between steady economic development and ecological environmental protection while guaranteeing the improvement of agricultural water use efficiency. The results show that the comprehensive development level of the system and its subsystems in the 11 provinces and cities of the Yangtze River Economic Belt has been steadily increasing, with a spatial pattern of "high in the west and low in the east", and the coupling coordination degree has entered the stage of mild dysfunction from localized moderate dysfunction, and the agricultural water use efficiency is the main limiting factor affecting the coordinated development of the composite system of the Yangtze River Economic Belt.

Keywords: CRITIC-entropy weight combination weight method; agricultural water use efficiency; coupling coordination; obstacle factor.

1 | Introduction

As one of the world's largest developing countries, China's agriculture not only carries the important responsibility of guaranteeing national food security, but is also directly related to the prosperity of the rural economy and the stability of the ecological environment. However, the problems of inefficient water use in agriculture, poor quality of agricultural economic development and deterioration of the agro-ecological environment are becoming more and more prominent, and have become bottlenecks restricting the sustainable development of agriculture.

There is a close interactive relationship between agricultural water use efficiency(Figure 1), agricultural economic development and agro-ecological environment. Agricultural production efficiency has a significant "threshold inhibition effect" on agricultural water consumption, which means that further improving production efficiency can effectively reduce agricultural water consumption[1].At the same time, healthy ecosystems support the development of water-efficient agriculture[2].

Effective utilization of water resources improves agricultural productivity, and the development of the agricultural economy provides governments with more financial resources to support water conservation in agriculture and improve the efficiency of water use in agriculture[3].

The prosperity of the agricultural economy can prompt agricultural enterprises to increase scientific and technological investment and product innovation, and promote the transformation and upgrading of the agricultural industry and sustainable development.

transformation, upgrading and sustainable development of the agricultural industry[4],Moreover, a good agro-ecological environment provides high-quality soil, water and climate conditions for agricultural production[5].

Currently, agricultural water consumption in the Yangtze River Economic Zone accounts for more than 50 percent of the regional water supply, but the efficiency of utilization is generally low, with problems such as serious waste of water resources and lagging irrigation technology needing to be urgently solved, and the problems of water pollution and ecological damage caused by the acceleration of industrialization and urbanization in recent years have become increasingly serious. To meet this challenge, it has become imperative to improve agricultural water use efficiency. This will not only effectively alleviate the water shortage problem, but also promote the sustainable and healthy development of the agricultural economy by reducing costs and enhancing efficiency[6].

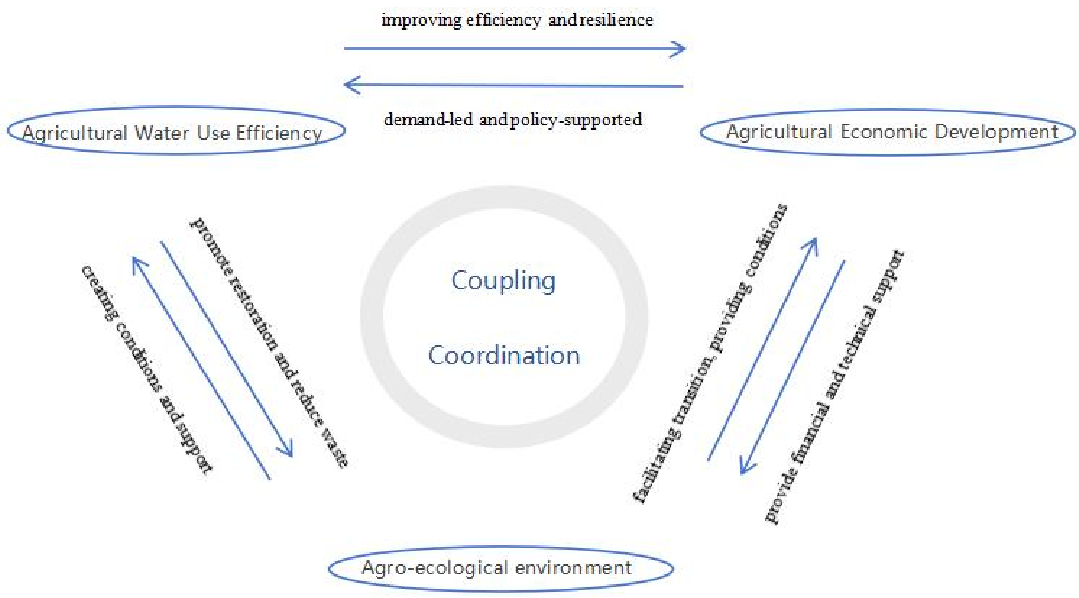

Figure 1 Mechanism of coupling coordination of composite systems

2 | Overview of the study area and research methodology

2.1 | Overview of the study area

The Yangtze River Economic Belt as an important economic region spanning 11 provinces and municipalities in China, it is not only the core zone of national food production and bears the important responsibility of guaranteeing national food security, but also a key region for promoting green economic development and ecological environmental protection by virtue of its unique geographic advantages and rich natural resources[7]. However, with the rapid economic growth and expanding population, the Yangtze River Economic Belt is facing the serious challenges of inefficient water use in agriculture and the intensified contradiction between economic development and ecological environment, which have become the main factors restricting the sustainable development of the region. As a traditional industry in the region, the water use efficiency of agriculture directly affects the cost, efficiency and competitiveness of agricultural production[8].

2.2 | Source of data

This paper analyzes the provincial panel data of 11 provinces and cities in the Yangtze River Economic Belt from 2007 to 2021. Through the selection of the above 30 data indicators, we explore the level of coordination of the coupling of the three systems of agricultural water use efficiency, economic development and ecological environment in the Yangtze River Economic Belt, and all the raw data used are from China Statistical Yearbook (2008-2022), China Rural Statistical Yearbook (2008-2022), China Environmental Statistical Yearbook (2008-2022), Provincial Water Resources Bulletin (2008-2022), National Bureau of Statistics (2008-2022), and

China Environmental Statistics Yearbook (2008-2022). China Environmental Statistics Yearbook (2008-2022), Provincial Water Resources Bulletin (2008-2022), National Bureau of Statistics (2008-2022), and Provincial Statistical Bulletins on National Economic and Social Development. Due to the limitation of data availability, interpolation was used to fill in the very few missing data.

2.3 | Research Methods

2.3.1 | CRITIC-entropy weight combination weighting method

When X_{ij} is a positive indicator:

$$X_{ij}^{'}=\frac{X_{ij}-\min(X_{ij})}{\max(X_{ij})-\min(X_{ij})} \tag{1}$$

When X_{ij} is a negative indicator:

$$X_{ij}^{'}=\frac{\max(X_{ij})-X_{ij}}{\max(X_{ij})-\min(X_{ij})} \tag{2}$$

Entropy weighting method to solve for weights:

$$P_{ij}=\frac{X_{ij}^{'}}{\sum_{i=1}^{n}X_{ij}^{'}},\quad e_j=-\frac{\sum_{i=1}^{n}P_{ij}\ln(P_{ij})}{\ln(n)},\ d_j=1-e_j,\quad \theta_j=\frac{d_j}{\sum_{j=1}^{m}d_j} \tag{3}$$

The CRITIC method solves for weights:

$$\overline{X}_j=\frac{1}{n}\sum_{i=1}^{n}X_{ij},\quad \sigma_j=\sqrt{\frac{\sum_{i=1}^{n}\left(X_{ij}-\overline{X}_j\right)^2}{n-1}},\quad R_j=\sum_{j=1}^{m}\left(1-r_{ij}\right),\quad C_j=\sigma_j\times R_j,\quad \eta_j=\frac{C_j}{\sum_{j=1}^{h}C_j} \tag{4}$$

Calculate the portfolio weights for each indicator:

$$W_j=\alpha_1\theta_j+\alpha_2\eta \tag{5}$$

Comprehensive evaluation methodology:

$$
\begin{cases}
U_A = \sum_{j=1}^{a} W_{1j} \cdot A'_{ij} \\
U_B = \sum_{j=1}^{b} W_{2j} \cdot B'_{ij} \\
U_C = \sum_{j=1}^{c} W_{3j} \cdot C'_{ij}
\end{cases}
\tag{6}
$$

Modified Coupled Coordination Degree Model:

$$
C = \sqrt{\left[1 - \frac{\sum_{i>j,j=1}^{n} \sqrt{(U_i - U_j)^2}}{\sum_{m=1}^{n-1} m}\right] \times \left(\prod_{i=1}^{n} \frac{U_i}{\max U_i}\right)^{\frac{1}{n-1}}}
\tag{7}
$$

Coordination formula:

$$
T = \beta_1 U_1 + \beta_2 U_2 + \beta_3 U_3,\quad \beta_1 + \beta_2 + \beta_3 = 1,\quad D = \sqrt{C \times T}
\tag{8}
$$

Table 1 Assessment basis and categorization criteria for the degree of coupling coordination

Interval	Broad category	Coupling harmonization degree C	Harmonization development degree D
[0,0.1)		Extreme Dissonance	Extreme Dissonance
[0.1,0.2)		Severe Dissonance	Severe Dissonance
[0.2,0.3)	Dislocated decline	Moderately dysfunctional	Moderately dysfunctional
[0.3,0.4)		Mildly disordered	Mildly disordered
[0.4,0.5)		Threatened disorder	Threatened disorder
[0.5,0.6)	Excessive category	Barely coupled	Barely coordinated
[0.6,0.7)		Primary coupling	Primary coordination
[0.7,0.8)	Coordinated developmental category	Intermediate Coupling	Intermediate Coordination
[0.8,0.9)		Good coupling	Good coordination
[0.9,1]		Quality coupling	Quality coordination

obstacle degree:

$$I_{ij} = 1 - S_{ij}, \quad F_j = \frac{W_j I_{ij}}{\sum_{j=1}^{m} W_j I_{ij}} \times 100\% \tag{9}$$

2.4 | Results and Analysis

2.4.1 | Level of integrated development of the three systems of agricultural water use efficiency, economic development and ecological environment in the Yangtze River Economic Zone

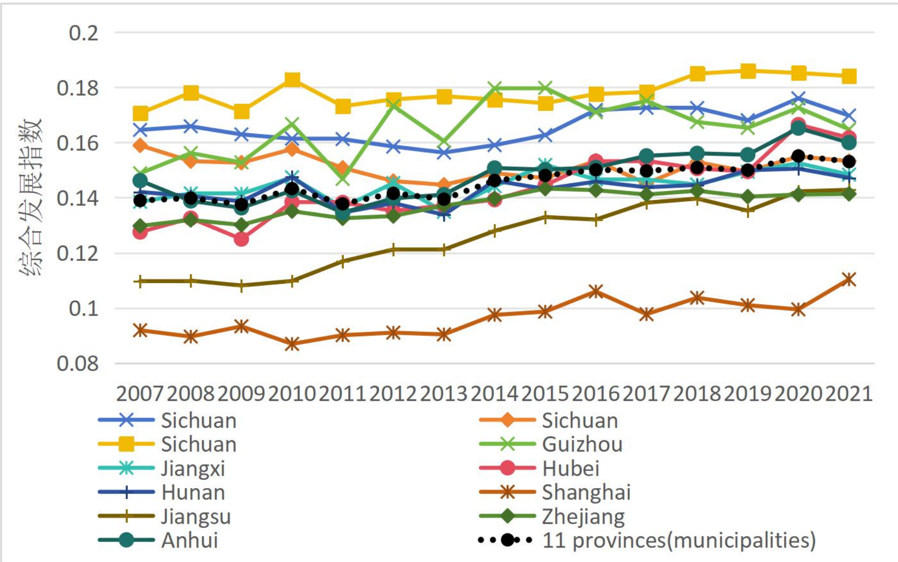

Figure 2 Mechanism of coupling Development Level of "Agricultural Water Use Efficiency - Economic Development - Ecological Environment" in the Yangtze River Economic Zone coordination of composite systems

According to Figure 2, from the Yangtze River Economic Zone "agricultural water use efficiency - economic development - ecological environment" overall comprehensive development index, it can be clearly seen that Yunnan Province has the highest comprehensive development index, followed by Sichuan Province, Guizhou Province, Chongqing Municipality to maintain the priority position. The comprehensive development index of Shanghai is the lowest among the eleven provinces (municipalities) in the Yangtze River Economic Belt. It is not difficult to find that the overall development level of agricultural water use efficiency, agricultural economic development and agro-ecological environment in the Yangtze River Economic Belt shows a slow fluctuation and increase, and the comprehensive development index presents the development characteristics of "upstream leading, middle middle, and downstream lagging behind", and the level of coordination as a whole presents the spatial differentiation pattern of "west high and east low".

2.4.2 | Characteristics of spatial and temporal evolution of the coupled coordination of the three systems of agricultural water use efficiency, economic development and ecological environment in the Yangtze River Economic Zone

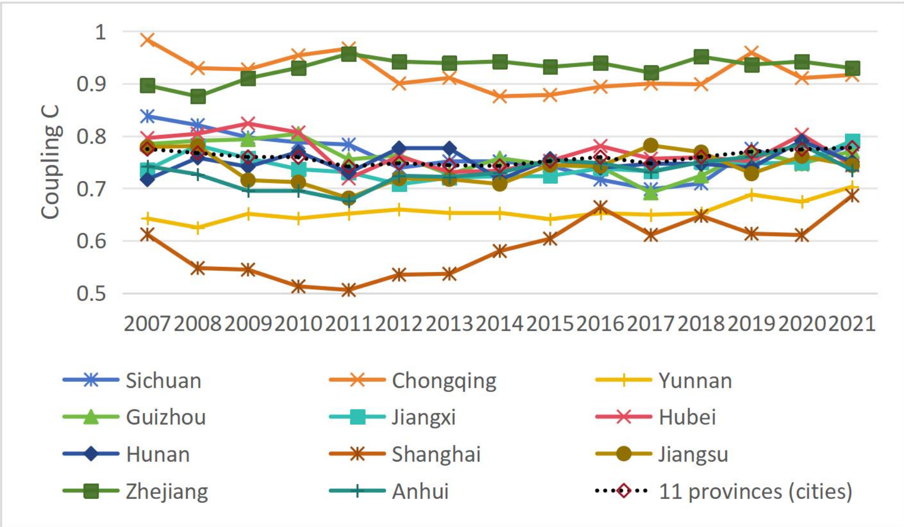

Figure 3 Composite System Coupling of Eleven Provinces (Municipalities) in the Yangtze River Economic Belt, 2007-2021

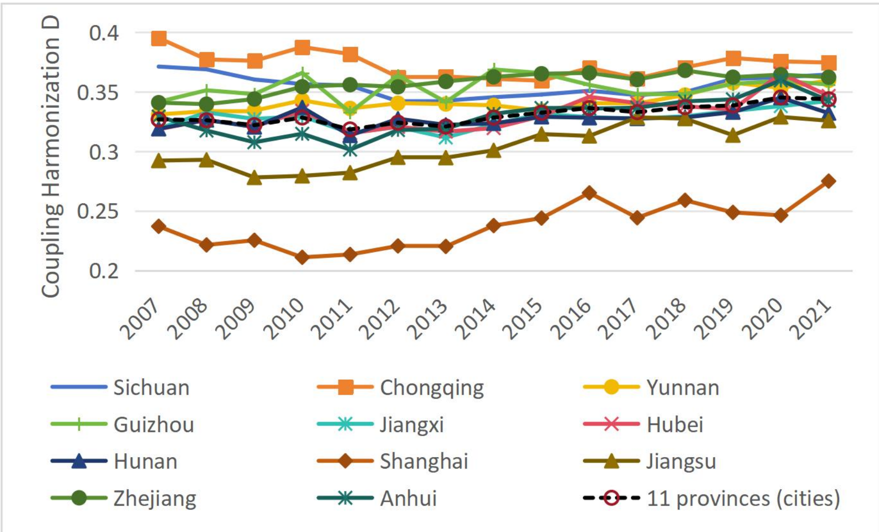

Figure 4 Coupled Coordination of Composite Systems in Eleven Provinces (Municipalities) of the Yangtze River Economic Belt, 2007-2021

Figure 3 and Figure 4 show the inter-annual changes of the coupling degree and coupling coordination degree of the composite system of "agricultural water use efficiency-economic development-ecological environment" in the Yangtze River Economic Zone from 2007 to 2021, In 2007, the coupling degree of the eleven provinces (municipalities) was in the stage of coordinated development, indicating that the coupling degree of the eleven provinces (municipalities) was in the stage of coordinated development, and the coupling degree of the eleven provinces (municipalities) was in the stage of coordinated development. In this stage, the provinces (cities) of the Yangtze River Economic Belt may pay more attention to the protection of the ecological environment, the economical use of resources and the sustainable development of the economy, which also lays a solid foundation for the future long-term development.In 2012, except for Shanghai, which is barely coupled in the transition stage, all the other provinces (municipalities) are in the stage of coordinated development, due to the fact that Shanghai, as the center of China's economy, finance, trade and shipping, has a significant difference in its economic structure and scale is significantly different from other provinces and cities. This difference leads to different challenges and opportunities in the development process of Shanghai, thus affecting its coupling degree. Since 2015, the eleven provinces and cities have entered the stage of coordinated development, and the largest increase in coupling degree over the past 15 years is in Shanghai, with an increase of 12.1%, because the 2014 government work report explicitly proposed "building the Yangtze River Economic Belt by relying on the golden waterway." This strategy has been formalized as a national strategy[9]. As the leading city of the Yangtze River Economic Belt, Shanghai benefits from this strategic positioning and gains more development opportunities and resources. From Figure 6, it can be seen that all eleven provinces (municipalities) in the Yangtze River Economic Belt are in the category of dysfunctional decline during the study period, and the whole is maintained above 0.32. The mean value of coupling coordination degree rises from 0.327 in 2007 to 0.344 in 2021, all of which are in a mildly dysfunctional state. Except for Sichuan and Chongqing, which show a negative trend, the coupling degree of coordination of all provinces (municipalities) has increased to varying degrees and is on a steady upward trend. Among them, Shanghai has the largest increase, from 0.237 in 2007 to 0.275 in 2021, and the coupling coordination degree of Chongqing has been at a high level for a long time. According to the figure, Shanghai in 2007-2021 and Jiangsu in 2007-2013 are in the state of moderate dissonance, while all other provinces and cities are in the state of mild dissonance.

3 | Diagnosis of disorder factors

Table 2 Main obstacle factors to the harmonized development of composite systems (2007-2021)

regions	subsystems	First obstacle factor	Obstacle degree	Second obstacle factor	Obstacle degree	Third obstacle factor	Obstacle degree
Sichuan	A	A11	7.00%	A21	6.39%	A22	5.47%
	B	B31	5.74%	B42	5.67%	B11	4.39%

	C	C21	4.55%	C32	4.30%	C11	3.15%
Chongqing	A	A21	6.93%	A22	6.00%	A23	4.56%
	B	B31	5.56%	B42	5.20%	B11	4.01%
	C	C12	5.09%	C32	4.86%	C21	4.46%
Yunnan	A	A11	9.13%	A21	8.36%	A22	6.40%
	B	B42	6.55%	B31	6.37%	B11	5.06%
	C	C21	4.70%	C32	2.70%	C22	2.44%
Guizhou	A	A21	7.98%	A22	6.54%	A11	6.15%
	B	B42	6.21%	B31	5.89%	B11	4.80%
	C	C21	5.05%	C32	4.21%	C12	4.15%
Jiangxi	A	A11	6.91%	A22	5.55%	A23	5.06%
	B	B42	4.90%	B31	4.25%	B11	4.20%
	C	C24	4.56%	C32	4.49%	C21	4.38%
Hubei	A	A22	5.75%	A23	5.60%	A11	5.12%
	B	B42	4.79%	B31	4.50%	B12	3.98%
	C	C22	4.41%	C21	4.41%	C32	4.41%
Hunan	A	A11	6.16%	A22	6.03%	A23	5.56%
	B	B42	4.89%	B51	4.02%	B12	3.64%
	C	C24	4.46%	C21	4.26%	C22	4.16%
Shanghai	A	A32	4.37%	A23	3.08%	A22	3.03%
	B	B22	4.58%	B41	4.52%	B21	4.51%
	C	C12	4.76%	C32	4.62%	C14	4.54%
Jiangsu	A	A12	5.75%	A32	4.50%	A11	4.51%
	B	B22	3.79%	B21	3.78%	B51	3.74%
	C	C32	4.85%	C13	4.71%	C11	4.69%
Zhejiang	A	A32	5.15%	A11	4.23%	A22	3.70%

	B	B41	4.77%	B21	4.47%	B22	4.41%
	C	C32	5.39%	C24	4.54%	C14	4.45%
Anhui	A	A11	5.71%	A23	5.64%	A22	5.21%
	B	B42	5.04%	B51	4.29%	B11	4.10%
	C	C32	5.24%	C31	4.71%	C13	4.36%

The first three main obstacle factors of each subsystem were calculated from the provinces, cities and the whole and arranged in order of magnitude, as shown in Table y. The cumulative degree of obstruction of the first three main obstacle factors of the agricultural water use efficiency, agricultural economic development and agro-ecological environment subsystems ranged from 10.48%-23.89%, 11.31%-17.98%, and 9.84%-14.41%, respectively, which indicated that the corresponding first The three obstacle factors have the strongest degree of hindrance to the agricultural water use efficiency subsystem, the second strongest degree of hindrance to the agricultural economic development subsystem, and the weakest degree of hindrance to the agricultural ecological environment development subsystem.

Indicators such as per capita water-saving irrigated area, proportion of agricultural water use, proportion of water-saving irrigated area, and effective irrigation rate of arable land in the agricultural water use efficiency subsystem and indicators such as disposable income of agricultural residents, per capita gross agricultural output value, agricultural machinery power per unit sown area, and proportion of agricultural value-added in the agricultural economic development subsystem are the key factors affecting the coordinated development of the agricultural water use efficiency-agricultural economic development-agricultural ecology in the Yangtze River Economic Belt provinces and cities. The indicators of the agricultural ecological environment subsystem, such as the area of planted forests, the proportion of ecological water use, the per capita cultivated land area, and the intensity of agricultural fertilizer application, are also important factors affecting the coordinated development of the three, but the degree of influence is relatively small.In summary: ① Optimizing agricultural water management is a top priority. The Yangtze River Economic Belt should vigorously promote efficient water-saving irrigation technologies, such as drip irrigation and sprinkler irrigation, to reduce the waste of water resources, as well as to enhance the per capita water-saving irrigation area and the proportion of water-saving irrigation area. Meanwhile, a sound agricultural water use monitoring system should be established to implement precision irrigation strategies. In addition, the government should introduce relevant policies to encourage farmers to adopt water-saving equipment and measures[10],[11]. ② Adjusting the structure of agricultural industry and promoting green economic growth is also a key part. The Yangtze River Economic Belt should develop efficient, ecological, and recycling agriculture, optimize the agricultural industrial layout, and reduce the proportion of high water-consuming and highly polluting crops. At the same time, the disposable income of agricultural residents should be improved and the added value of agricultural products should be increased through technical training and market docking[12],[13]. ③ Strengthening agro-ecological environmental protection is equally important. The Yangtze River Economic Belt should expand the area of artificial afforestation and increase the forest coverage rate in order to enhance the service function of the ecosystem. At the same time, the proportion of ecological water use should be rationally planned to ensure the ecological water demand of natural water bodies such as rivers and lakes, and to maintain aquatic biodiversity. In addition, the intensity of agricultural fertilizer application should be strictly controlled, and technologies such as soil testing and formula fertilization and the substitution of organic fertilizers for chemical fertilizers should be promoted in order to reduce agricultural surface source pollution[14],[15].

4 | Conclusions

From 2007 to 2021, the overall development level of agricultural water use efficiency, agricultural economic development and agro-ecological environment in the Yangtze River Economic Belt showed a slow fluctuation and increase, and the comprehensive development index showed the development characteristics of "upstream leading, middle reaches in the middle, and downstream lagging behind", and the degree of coupling coordination showed a fluctuating upward trend, and constantly tended to be optimized. The fluctuation range of the data is small, and the overall curve is gentle, and the degree of coordination is lower than the degree of coupling, indicating that the overall coordinated development is relatively lagging behind. The study shows that the first three obstacle factors corresponding to each subsystem have the strongest degree of blockage to the agricultural water use efficiency subsystem, followed by the city's agricultural economic development subsystem, and the weakest degree of blockage to the agricultural ecological environment development subsystem.

References

[1] JIN Wei, LIU Shuangshuang, ZHANG Ke, et al. Impact of agricultural production efficiency on agricultural water use[J]. Journal of Natural Resources,2018,33(08):1326-1339.

[2] Baron, Jill S. et al. "Sustaining Healthy Freshwater Ecosystems." Journal of Contemporary Water Research & Education 127 (2003): 52-58.

[3] Wen Qiuliang. Financial support for "water-saving agriculture" is of great importance[J]. Economic Research Reference, 1996,(Z6):44. DOI:10.16110/j.cnki.issn2095-3151.1996.z6.067.

[4] LI Yan, MA Jing, DU Yong, et al. Scientific and technological innovation boosts the high-quality development of agriculture[J]. Journal of Agronomy,2020,10(12):11-13.

[5] WU Bin,YAN Xiaohong,ZHOU Chunmiao. Soil and water conservation is the basis for

sustainable agricultural development[J]. Research on Soil and Water Conservation,1998,(02):60-62.

[6] LUO Fang, TIAN Miao, SUN Caihong, XU Dan. Spatial-temporal differentiation and influencing factors of agricultural water resource use efficiency in Yangtze River Economic Belt[J]. , doi: 10.16232/j.cnki.1001-4179.2020.02.001.

[7] WANG Zhen,YANG Xin,WANG Xiaojuan,SHANG Yongmin. Report on the Development of the Yangtze River Economic Belt (2020～2021). Beijing. Social Science Literature Publishing House.2021-12.217-241

[8] Xinhua. A powerful engine for high-quality development - Review of in-depth promotion of the Yangtze River Economic Belt [EB/OL] (2018-08-11) [2024-8-26].https://www.gov.cn/xinwen/2018-08/11/content_ 5313262.htm

[9] Guo Xiaoting. Birth of the Yangtze River Economic Belt Strategy [EB/OL] (2014-09-10) [2024-08-27]. https://www.gov.cn/xinwen/2014-09/10/content_2748306.htm

[10] LIU Dong,LI Xiaoling. Prospects and measures for water conservation in the Yangtze River Basin[J]. Yangtze River Basin Resources and Environment,2003,12(4):340-344. DOI:10.3969/j.issn.1004-8227.2003.04.009.

[11] Wang Yusheng. Thoughts on the Development of Water-saving Irrigation in the Yangtze River Basin[J]. People's Yangtze River,2003,34(07):10-11.

[12] Li Yurui, Yang Qianlong, Cao Zhi. Current characteristics and model transformation of agricultural development in the Yangtze River Economic Belt[J]. Progress in Geoscience,2015,34(11):1458-1469.

[13] YANG Qian,HU Feng,CHEN Yunhua,et al. Strategies and suggestions for green development of the Yangtze River Economic Belt based on the theory of water economics[J]. Environmental Protection,2016,44(15):36-40.DOI:10.14026/j.cnki.0253-9705.2016.15.006

[14] Huang Guoqin. On the green development of agriculture in the Yangtze River Economic Belt[J]. China Agronomy Bulletin,2021,37(30):154-164.

[15] Shi Rui. Analysis of redundancy in fertilizer application and motivation of farmers' behavior in Heilongjiang Province[D]. Heilongjiang: Northeast Forestry University, 2021.