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Temporal and Spatial Difference Analysis and Impact Factors of Water Ecological Civilization Level: Evidence from Jiangxi Province, China

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Abstract: The water environment quality is not high, the spatial and temporal distribution of water resources is uneven, and the water quality-induced water is in shortage in the world. Strengthening the construction of water ecological civilization is one of the important measures to solve these problems. We took China's Jiangxi Province and its prefecture-level cities as the research object, the water ecological civilization level was measured from the two dimensions of time and space by principal component analysis, and based on the panel data of prefecture-level cities from 2011 to 2020, the panel data model was used to empirically analyze the impact factors of water ecological civilization. The results show that: (1) The level of water ecological civilization in Jiangxi Province shows a fluctuating upward trend, in which the level of water ecological civilization first increased, then decreased, and then increased from 2013 to 2020. (2) Water ecology is the key to affecting water ecological civilization, and cities with abundant natural endowments of water resources have higher scores for water ecological civilization. (3) There are significant differences in the level of water ecological civilization in different cities in Jiangxi Province; the level of water ecological civilization in southern Jiangxi and central Jiangxi is generally higher than that in northern Jiangxi; among the 11 prefecture level cities, Ji'an, Fuzhou, Jiujiang, Yichun, Ganzhou, and Shangrao have a high level of water ecological civilization. (4) Industrial structure, educational investment, and government governance level have significantly improved the level of water ecological civilization. Environmental pollution is not conducive to improving the level of water ecological civilization. There is an inverted U curve between the level of urbanization and the level of water ecological civilization. Accordingly, all prefecture-level cities in Jiangxi Province need to implement new development concepts and innovation-driven strategy, make up for shortcomings, and strengthen weak points according to their own natural endowments of water resources, such as optimizing the industrial structure, increasing investment in education, improving the level of government governance, and strengthening the connotation construction of urbanization, so as to promote the construction of water ecological civilization in Jiangxi Province. The research results also provide a reference for other countries similar to Jiangxi Province to solve the problem of water pollution, alleviate the pollution-induced water shortage, and improve the water ecological environment in the process of economic development.

Keywords: principal component analysis; water ecological civilization; temporal and spatial differences; impact factors

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1. Introduction

Since ancient times, water resources, as the basic material for all production and life in human society, have played a huge role in national economic construction and social development. With the rapid development of China's economy and society, the continuous acceleration of industrialization and urbanization, the contradiction between supply and demand of water resources in China, the deterioration of the water environment, the shortage of water resources, and the degradation of water ecology have become more and more serious, which seriously restricts the high-quality development of China's economy and society. Accordingly, China has implemented an ecological civilization strategy, and the Ministry of Water Resources has also selected cities with better conditions across the country to carry out the pilot work of water ecological civilization in 2013 and 2014 (water ecological civilization refers to that human beings follow the concept of harmony between man and water in order to realize the sustainable utilization of water resources and support the harmonious development of economy and society; it is an important part and basic content of ecological civilization). Among them, Nanchang, Xinyu, and Pingxiang in Jiangxi Province were successively selected as pilot cities for water ecological civilization and passed the acceptance test. In the context of the construction of water ecological civilization, the water environment quality in Jiangxi Province has been more improved, but the uneven spatial and temporal distribution of water resources and the water quality-induced water shortage will affect the construction of the National Ecological Civilization Experimental Zone in Jiangxi Province and the promotion of the "Jiangxi Sample" of beautiful China [1]. Therefore, studying the construction of water ecological civilization in Jiangxi Province is not only to respond to the requirements of building a civilized Jiangxi, but also to advocate a new development concept of harmony between human and water. This study aims to analyze the impact factors of water ecological civilization and enrich the theory of ecological civilization and improve the research content of sustainable development theory. It provides a new empirical basis for improving water ecological environment in China. As the water ecological environment has also deteriorated in some other developing countries, this study also aims to provide a reference for other developing countries similar to China to solve the problem of water pollution, alleviate the pollution-induced water shortage, and improve the water ecological civilization in the process of economic development.

With the continuous advancement of the pilot construction of water ecological civilization cities, how to define water ecological civilization and evaluate the level of water ecological civilization has gradually become a hot issue for scholars at home and abroad [2,3]. In the interpretation of the connotation of water ecological civilization, Zuo believes that water ecological civilization consists of four aspects. Among them, advocating harmonious coexistence between man and nature is the core of water ecological civilization, and saving water resources is the top priority of water ecological civilization construction. Protection of water ecology is the key to the construction of water ecological civilization [4]. Huang pointed out that water ecological civilization is closely related to society, economy, culture, and value judgment. At the regional level, it can be understood as the organic unity of resource security, ecological security, social security, and economic security, and on this basis, four major systems for the construction of water ecological civilization are qualitatively constructed, namely water resources, water ecology, water economy, and water society [5]. In terms of evaluation methods, some scholars use set pair analysis method, fuzzy comprehensive evaluation method, projection pursuit method, AGA-FAHP (Fuzzy Analytic Hierarchy Process Evaluation Method based on Accelerating Genetic Algorithm), connection number method, and AHP (Analytic Hierarchy Process) to analyze water ecological civilization [6–10]. In the research area, the existing literature has measured the water ecological civilization of the Yangtze River Economic Belt, the Yellow River Basin, the Nansihu Basin, Zhongshan City, Pizhou City, Lanzhou City, the Yangtze River Delta urban agglomeration, and the Guanzhong urban agglomeration by constructing an index system [11–20].

To sum up, it is found that the existing literature mainly focuses on the evaluation of water ecological civilization in river basins, cities, and urban agglomerations, and very little of the literature has studied the provincial level from a quantitative perspective. In terms of research objects, there is a lack of analyzing the level of water ecological civilization from the two dimensions of time and space. In addition, most of the literature is still on the evaluation of water ecological civilization, and very little of the literature has studied its impact factors. Zhu et al. used quantitative analysis methods to discuss the impact factors of water ecological civilization [21]; they only analyzed the relationship between new urbanization and water ecological civilization through the unit root and Granger causality test, and did not construct a panel data model for empirical analysis of the impact factors, Fan et al. only used water ecological civilization as an explanatory variable, and used PSM-DID to verify whether water ecological civilization can improve China's total factor production efficiency [22]. Scholars mainly discuss the influencing factors of ecological civilization, water resource utilization efficiency, water pollution, water footprint, and water resources carrying capacity [23–30].

This paper first uses the principal component analysis method to calculate the level of water ecological civilization in Jiangxi Province from 2011 to 2020, and then analyzes the spatial differences of water ecological civilization in prefecture-level cities in Jiangxi Province in 2020. Finally, the panel data model is used to empirically analyze the factors affecting water ecological civilization, in order to provide a reference for the construction of water ecological civilization in Jiangxi Province in the future.

2. Material and Methods

2.1. Study Area

The Jiangxi is located at latitude 24°29′~30°04′ north, longitude 113°34′~118°28′ east. It is located in southeast China, in the middle and lower reaches of the Yangtze River, in the middle subtropical zone, with a significant monsoon climate and four distinct seasons. The annual average temperature of the whole province is about 18.4 °C, with the average annual precipitation of 1698.63 mm and the average annual sunshine hours of 1478.6 h. The whole year of Jiangxi has a mild climate, with sufficient sunshine, plentiful rainfall, and a long frost-free period. The province covers an area of 166,900 km^2, with a total population of more than 45.18 million, and is divided into 11 cities (Jingdezhen, Jiujiang, Shangrao, Nanchang, Yingtan, Yichun, Xinyu, Fuzhou, Pingxiang, Ji'an, and Ganzhou), as shown in Figure 1. Further, Jiangxi Province is endowed with rich water resources and dense river networks. There are more than 2400 rivers of various sizes in Jiangxi Province, which have a combined total length of about 18,400 km. Most of them enter Poyang Lake, which in turn empties into the Yangtze River. The five major rivers are Gan River, Fu River, Xin River, Xiu River, and Rao River. The Gan River winds along 751 km, which is the biggest river of the province, and the second tributary of the Yangtze River in water volume. Flowing through the entire length of the province from south to north, it enters Ganzhou to Hukou, and then pours into the Yangtze River, with navigation mileage of over 5000 km. Poyang Lake is the largest fresh lake in China, and the biggest water assembling basin of Jiangxi Province. It is the huge volume moderator of the Yangtze River. It can be seen from Table 1 that Jiangxi Province is rich in water resources, but the spatial distribution of water resources is uneven in Jiangxi.

At present, the quality of water environment in Jiangxi has improved, and the ammonia nitrogen discharge of urban domestic sewage has decreased from 50,358 tons in 2013 to 18,157.08 tons in 2020, which is a significant decrease; the discharge of chemical oxygen demand of urban domestic sewage has dropped from 389,701 tons in 2013 to 218,293.83 tons in 2020, which is a significant decrease; the utilization efficiency of water resources has been significantly improved, of which the water consumption per 10,000 USD of added value of manufacturing has decreased from 150164.70 \$/m^3 in 2013 dropped to 86284.85 \$/m^3 in 2020, with an average annual decrease of 7.61%, and the water consumption per 10,000 USD of GDP decreased from 298714.72 \$/m^3 in 2013 to 145596.10 \$/m^3 in 2020, with an average annual decrease of 9.76%. The water pollution treatment capacity has been significantly improved, the sewage treatment rate has increased from 83.1% in 2013 to 97.48% in 2020, the number of wastewater treatment facilities has increased from 2543 in 2013 to 4707 in 2020, and the density of drainage pipes has increased from 9.18 km/km^2 in 2013 to 11 km/km^2 in 2020. Although the above indicators have been improved, the ammonia nitrogen discharge of urban domestic sewage, the discharge of chemical oxygen demand of urban domestic sewage, the water consumption per 10,000 USD of added value of manufacturing, and the water consumption per 10,000 USD of GDP are still higher than the national average level in the same period, and the sewage treatment rate, the number of wastewater treatment facilities, and the density of drainage pipes are still lower than the national average level in the same period. Therefore, it is necessary to promote the construction of Jiangxi water ecological civilization.

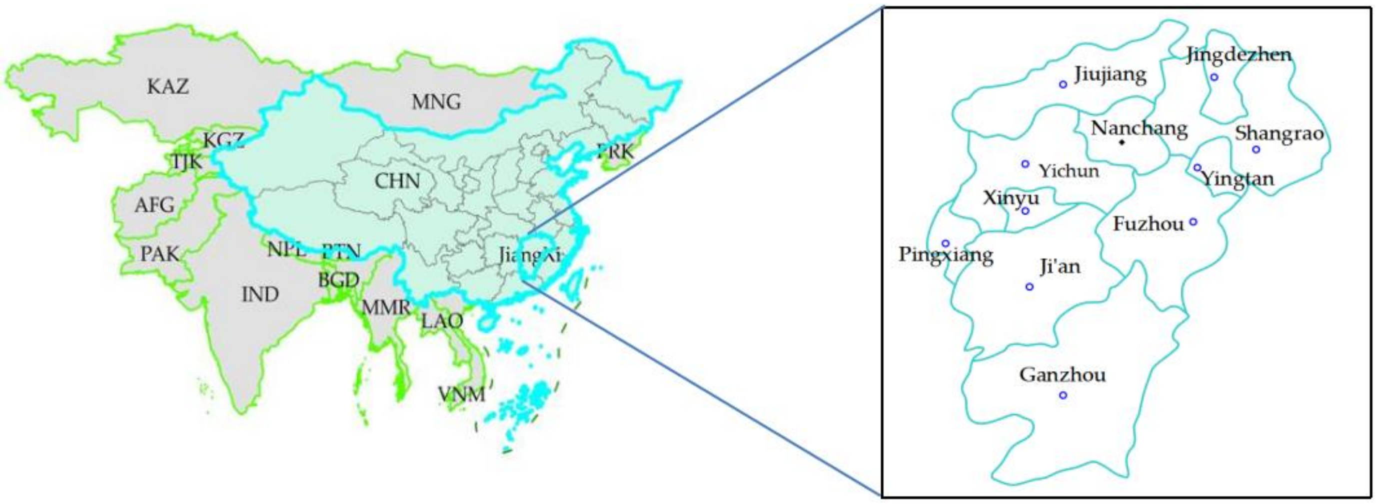

Figure 1. Map of Jiangxi Province, China. Note: KGZ: Kyrgyzstan, AFG: Afghanistan, NPL: Nepal, BTN: Bhutan, LAO: Laos, MNG: Mongolia, PAK: Pakistan, BGD: Bangladesh, KAZ: Kazakhstan, TJK: Tajikistan, MMR: Myanmar, IND: India, PRK: People's republic of Korea, VNM: Vietnam, CHN: China.

Table 1. Annual precipitation and total water consumption of Jiangxi Province in 2020.

Region	Annual Precipitation (100 Million m^3)	Total Water Consumption (100 Million m^3)
Jiangxi Province	3093.70	244.12
Nanchang	143.84	30.28
Jingdezhen	124.27	7.80
Pingxiang	71.60	6.77
Jiujiang	367.81	22.12
Xinyu	56.92	7.79
Yingtan	73.00	6.40
Ganzhou	590.88	33.03
Ji'an	428.14	30.70
Yichun	379.06	47.24
Fuzhou	361.15	22.26
Shangrao	497.03	29.73

2.2. Construction of Indicator System

According to the situation of water resources in Jiangxi Province and referring to the evaluation literature of water ecological civilization [31–33], to comprehensively analyze the advantages and disadvantages of the existing indicators, and considering the connotation of water ecological civilization and the availability of data, we constructed an evaluation indicator system for water ecological civilization in Jiangxi Province, as shown in Table 2. The evaluation indicator system of water ecological civilization in Jiangxi Province includes water ecological system, water economic system, and water social system. The water ecological system includes 10 indicators, such as annual precipitation, surface water resources, and groundwater resources; the water economic system includes 9 indicators such as the water consumption per 10,000 USD of added value of manufacturing, the water consumption per 10,000 USD of GDP, and the average water consumption per mu of farmland irrigation; the water social system mainly includes 2 indicators such as the per capita park green space area and the green coverage rate of built-up areas.

Table 2. Indicator system.

Target Layer	Criterion Layer	Indicator Layer	Dimension	Indicator Attribute
Jiangxi Province water ecological civilization evaluation indicator system	Water ecological system	Annual precipitation	10^8 m^3	Positive indicator
		Surface water resources	10^8 m^3	Positive indicator
		Groundwater resources	10^8 m^3	Positive indicator
		Total water consumption	10^8 m^3	Inverse indicator
		Ecological environment water consumption ratio	%	Positive indicator
		Groundwater exploitation coefficient	%	Inverse indicator
		Ammonia nitrogen emission of urban domestic sewage	t	Inverse indicator
		Chemical oxygen demand discharge of urban domestic sewage	t	Inverse indicator
		Number of wastewater treatment facilities	set	Positive indicator
		Wastewater treatment facility treatment capacity	10^8 t/d	Positive indicator
	Water economic system	The water consumption per 10,000 USD of added value of manufacturing	$m^3/10^4$ $	Inverse indicator
		The water consumption per 10,000 USD of GDP	$m^3/10^4$ $	Inverse indicator
		The average water consumption per mu of farmland irrigation	m^3	Inverse indicator
		The utilization ratio of water resources	%	Inverse indicator
		Per capita water consumption	m^3	Inverse indicator
		Proportion of investment in water-related affairs in general budget revenue	%	Positive indicator
		Sewage treatment rate	%	Positive indicator
		The density of drainage pipes	km/km^2	Positive indicator
		Water penetration rate	%	Positive indicator
	Water social system	The per capita park green space area	m^3	Positive indicator
		The green coverage rate of built-up areas	%	Positive indicator

2.3. Model Construction and Variable Measurement

2.3.1. Model Construction

Based on the existing literature on the impact factors of water resources utilization, water pollution control, and water resources carrying capacity [34–37], we specify the water ecological civilization score (*WE*) as the dependent variable and take economic growth (*EG*), industrial structure (*IN*), urbanization level (*UR*), education investment (*ED*), government governance level (*GI*), and environmental pollution (*HJ*) as the independent variables. We construct and estimate the following models:

$$WE_{it} = C + \alpha_1 EG_{it} + \alpha_2 IN_{it} + \alpha_3 UR_{it} + \alpha_4 UR_{it}^2 + \alpha_5 ED_{it} + \alpha_6 GI_{it} + \alpha_7 HJ_{it} + u_i + \varepsilon_{it} \quad (1)$$

Among them, i and t represent the i cities (the sample cities are 11) and the year (the sample period is 2011–2020), respectively. Since there may be an environmental Kuznets curve between urbanization and the ecological environment [38,39], the square of the urbanization level is added to the model. On the basis of referencing existing research results, we expect that the relationship between economic growth and water ecological civilization is uncertain, which may be positive or negative, it depends on the stage of economic development; we expect that industrial structure, education investment, and government governance level will help improve the level of water ecological civilization, and that environmental pollution is not conducive to improving the level of water ecological civilization; we also expect that there is a nonlinear relationship between urbanization level and the level of water ecological civilization.

2.3.2. Variable Measurement

First, we use the evaluation indicator system of water ecological civilization in Table 2 to measure the water ecological civilization of prefecture-level cities in Jiangxi Province from 2011 to 2020. Since the result has negative values, the Max-Min method is used for normalization. Secondly, the per capita GDP, urban population/total population, education expenditure/general public budget expenditure, and general public budget expenditure/GDP are used to measure economic growth, urbanization level, education investment, and government governance level, respectively. Referring to the calculation method of Yuan and Zhu [40], the Theil index is used to measure the industrial structure. We select industrial wastewater discharge, industrial waste gas discharge, industrial SO_2 discharge, industrial ammonia nitrogen discharge, and industrial powder (dust) discharge indicators, and we use the entropy method to calculate the comprehensive score to measure environmental pollution.

2.4. Data

The original data of each indicator of water ecological civilization in this paper during the period 2011–2020 were collected from the Jiangxi Statistical Yearbook, the Jiangxi Water Resource Bulletin, the China Water Resources Bulletin, the China Urban Statistical Yearbook, and Jiangxi National Economic and Social Development Statistical Bulletin. The original data of the independent variables were collected from the Jiangxi Statistical Yearbook and the China Urban Statistical Yearbook. Some data were missing, which were filled using linear interpolation and mean methods.

3. Results and Discussion

3.1. Evaluation Results

3.1.1. Time Dimension Analysis

Based on the principal component analysis method and using SPSS 22.0, this paper first standardized the raw data of various indicators of water ecological civilization in Jiangxi Province, eliminating the influence of different dimensions on the evaluation results; secondly, the correlation matrix eigenvalue, variance contribution rate, and cumulative variance contribution rate were calculated, as shown in Table 3. We can see that the eigenvalues of the first four principal components are 8.888, 6.369, 2.289, and 1.925, which are all greater than 1, and the cumulative variance contribution rate is 92.715%, indicating that the information represented by the four principal components can better reflect the water ecological civilization construction level of Jiangxi Province from 2011 to 2020, so the first four principal components are selected to replace the 21 indicators in Table 2.

Table 3. Eigenvalue, variance contribution rate, and cumulative variance contribution rate.

Principal Component	Eigenvalue	Variance Contribution Rate (%)	Cumulative Variance Contribution Rate (%)
1	8.888	42.322	42.322
2	6.369	30.328	72.650
3	2.289	10.899	83.548
4	1.925	9.1670	92.715

In order to further analyze the correlation between each indicator and each principal component, and obtain the principal component score, we need to use the principal component factor loading. The principal component factor loading matrix can be obtained by SPSS 22.0, as shown in Table 4.

Table 4. The principal component factor loading matrix.

Indicator Layer	Z1	Z2	Z3	Z4
Annual precipitation	0.466	0.852	0.167	−0.014
Surface water resources	0.409	0.862	−0.088	0.185
Groundwater resources	0.291	0.844	−0.129	0.319
Total water consumption	0.714	0.544	0.057	−0.408
Ecological environment water consumption ratio	0.944	−0.281	0.146	0.009
Groundwater exploitation coefficient	0.807	0.470	−0.056	0.301
Ammonia nitrogen emission of urban domestic sewage	0.789	−0.333	0.491	0.142
Chemical oxygen demand discharge of urban domestic sewage	0.693	−0.314	0.580	0.271
Number of wastewater treatment facilities	0.782	−0.322	0.246	−0.009
Wastewater treatment facility treatment capacity	−0.385	0.099	0.152	0.812
The water consumption per 10,000 USD of added value of manufacturing	0.896	−0.344	−0.239	0.119
The water consumption per 10,000 USD of GDP	0.876	−0.228	−0.418	0.018
The average water consumption per mu of farmland irrigation	0.221	0.808	0.064	−0.531
The utilization ratio of water resources	0.449	0.863	−0.061	0.117
Per capita water consumption	0.420	0.776	0.263	−0.343
Proportion of investment in water-related affairs in general budget revenue	0.312	−0.062	0.857	−0.033
Sewage treatment rate	0.785	−0.333	−0.420	−0.271
The density of drainage pipes	0.877	−0.177	−0.133	0.332
Water penetration rate	0.652	−0.672	−0.210	−0.086
The per capita park green space area	0.771	−0.241	−0.375	0.006
The green coverage rate of built-up areas	0.075	−0.665	0.353	−0.398

From Table 4, we can see that the first principal component Z1 has a larger load on indicators such as the total water consumption, ecological environment water consumption ratio, groundwater exploitation coefficient, ammonia nitrogen emission of urban domestic sewage, chemical oxygen demand discharge of urban domestic sewage, number of wastewater treatment facilities, the water consumption per 10,000 USD of added value of manufacturing, the water consumption per 10,000 USD of GDP, sewage treatment rate, the density of drainage pipes, water penetration rate, and the per capita park green space area. The above indicators mainly reflect the development level of water resources, sewage discharge, water use efficiency, and water conservancy project construction. It can be seen from Table 3 that the variance contribution rate of the first principal component Z1 is 42.322%, indicating that the development level of water resources, sewage discharge, water use efficiency, and water conservancy project construction have a huge impact on the water ecological civilization score in Jiangxi Province, and are important indicators that affect Jiangxi Province's water ecological civilization.

The second principal component Z2 has a larger load on indicators, such as annual precipitation, surface water resources, groundwater resources, the average water consumption per mu of farmland irrigation, the utilization ratio of water resources, and per capita water consumption. The above indicators mainly reflect the natural endowment of water resources and the utilization rate of water resources. The variance contribution rate of the second principal component is 30.328%, which indicates that the natural endowment of water resources and the utilization efficiency of water resources have a great impact on the water ecological civilization score in Jiangxi Province and are the basic indicators affecting the water ecological civilization in Jiangxi Province.

The third principal component Z3 and the fourth principal component Z4 have higher loads on proportion of investment in water-related affairs in general budget revenue and wastewater treatment facility treatment capacity, respectively. The former is a prerequisite for ensuring the continuous advancement of the construction of water ecological civilization, and it is also an important measure to improve the level of water ecological civilization; the latter is the key to ensuring the reuse of water resources.

According to the results of principal component analysis and the data in Tables 3 and 4, the proportion of the variance contribution rate of each principal component to the total variance contribution rate is used as the weight to calculate the comprehensive score of Jiangxi Province's water ecological civilization. The calculation formula is as follows:

$$Z = 0.4565 \times Z1 + 0.3271 \times Z2 + 0.1176 \times Z3 + 0.0989 \times Z4 \quad (2)$$

where the Z value is the comprehensive score of water ecological civilization in Jiangxi Province. The higher the Z value, the higher the level of water ecological civilization and vice versa. The results are shown in Table 5 and Figure 2.

Table 5. Comprehensive score of water ecological civilization in Jiangxi Province.

Year	Z	Ranking	Z1	Ranking	Z2	Ranking	Z3	Ranking	Z4	Ranking
2011	−2.6695	10	−4.0062	10	−2.7860	9	1.5551	3	−1.1352	7
2012	1.0679	4	−0.3755	7	3.6339	1	1.6481	2	−1.4479	9
2013	−1.6314	9	−3.1363	9	−1.3422	7	0.4223	4	1.9186	1
2014	−0.9628	7	−2.4825	8	−0.0227	4	−0.0259	6	1.8293	2
2015	1.0729	3	0.1062	5	2.9852	3	0.1242	5	0.3373	5
2016	1.4367	2	0.8848	3	3.3748	2	−0.6445	7	0.0467	6
2017	−0.1534	6	0.3995	4	−0.2664	5	−0.9146	8	−1.4268	8
2018	−1.2688	8	0.0862	6	−2.7907	10	−1.8458	9	−1.8031	10
2019	0.6249	5	1.9689	2	−0.2743	6	−2.4560	10	1.0578	3
2020	2.4835	1	6.5549	1	−2.5116	8	2.1371	1	0.6233	4

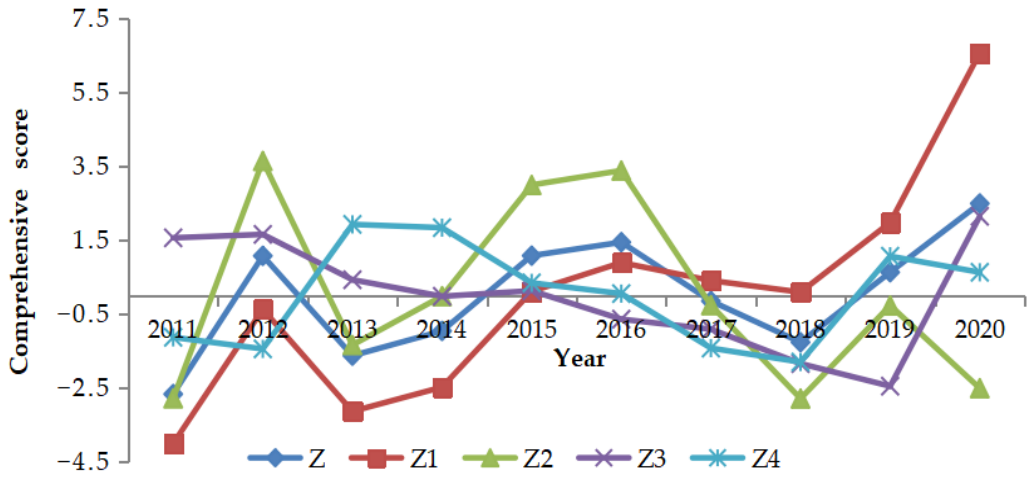

Figure 2. Comprehensive score of water ecological civilization in Jiangxi Province.

Firstly, from Table 5 and Figure 2, we can see that the evaluation scores of water ecological civilization in Jiangxi Province show a fluctuating upward trend, in which the score of water ecological civilization first increased, then decreased, and then increased from 2013 to 2020. The reason is that the Ministry of Water Resources started the pilot construction of water ecological civilization nationwide in 2013, and the main work includes implementing the strictest water resource management system, optimizing water resource allocation, strengthening water conservation management, strengthening water resource protection, promoting the protection and restoration of water ecosystems, strengthening ecological protection in water conservancy construction, improving guarantee and support capacity, and widely carrying out publicity and education. At the same time, in order to actively promote the "three red lines" of the strictest water resources management regulations, the Jiangxi Provincial Department of Water Resources has fully implemented the "River Chief System", revised the "Water Resources Regulations of Jiangxi Province", "Water Quotas for Main Products of Industrial Enterprises in Jiangxi Province", "Jiangxi Province Domestic Water Quota", and other documents, thus standardizing the utilization and development of water resources, so that the score of water ecological civilization rises first in this stage. However, as the marginal effects of the above-mentioned policies and documents decreased, the score of water ecological civilization declined. In 2018, due to the implementation of environmental protection policies and regulations, such as the Environmental Protection Tax Law, the Reform Plan for Compensation for Ecological Environmental Damage, and the newly revised Water Pollution Prevention and Control Law, the score of water ecological civilization rose again.

Second, from Table 5 and Figure 2, we can see that the positive and negative directions of the total score Z and the first principal component score Z1 are basically the same, because the first principal component accounts for a relatively large proportion. It reflects the impact of the development level of water resources, sewage discharge, water use efficiency, and water conservancy project construction on water ecological civilization. The reason for the gradual increase of the first principal component score Z1 is that the government attaches great importance to the construction of water ecological civilization; increases investment in water conservancy projects in the province; uses various media to promote water-saving culture, cultivate public awareness of water saving, and lay a good foundation for building a water-saving society; speeds up the laying of drainage pipes and the construction of sewage treatment plants; and improves the treatment rate of domestic sewage. Enterprises have improved the industrial reuse water rate by optimizing industrial structure, fulfilled their corporate social responsibility, and actively undertaken the treatment of industrial wastewater.

Third, from Table 5 and Figure 2, we can see that only in 2012, 2015, and 2016, the second principal component score Z2 was higher than the average level, because the second principal component reflects the impact of natural endowment of water resources and utilization rate of water resources on water ecological civilization, the surface water resources and groundwater resources in the natural endowment of water resources provide an important guarantee for economic and social development, and the abundant water resources formed by them have improved the score of water ecological civilization to a certain extent. The annual precipitation in 2012, 2015, and 2016 were 3614.53 $\times$ 108 m^3, 3464.76 $\times$ 108 m^3, and 3333.48 $\times$ 108 m^3, respectively, which were higher than the average level of 2902.07 $\times$ 108 m^3. Since 2016, the second principal component score Z2 has dropped sharply and is all negative. The reason is that the annual precipitation has decreased after 2016, and the average water consumption per mu of farmland irrigation, the utilization ratio of water resources, and per capita water consumption have all increased, which together restrict the score of the second principal component.

Fourth, from Table 5 and Figure 2, we can see that the third principal component score Z3 showed a downward trend as a whole during the pilot period of water ecological civilization construction from 2013 to 2019, but after 2019 it began to rise linearly to a certain extent, which reflects that under the background of water ecological civilization construction, Jiangxi Province's water ecological civilization construction has achieved remarkable results.

Finally, from Table 5 and Figure 2, we can also see that the fourth principal component score Z4 showed a gradual downward trend from 2013 to 2018, because with the advancement of industrialization, the increase in wastewater discharge far exceeded the treatment capacity of wastewater treatment facilities; while the fourth principal component scores Z4 in 2019 and 2020 were positive, because the number of wastewater treatment facilities increased from 3252 in 2018 to 4707 in 2020, which greatly improved the efficiency of wastewater treatment, thereby improving the score.

3.1.2. Spatial Dimension Analysis

In order to have a more comprehensive understanding of the water ecological civilization in Jiangxi Province, farmland effective irrigation coefficient is added to the water economic system; the indicator is added to make the number of indicators of the water ecological system and the water economic system the same, so that the impact of the water ecological system and the water economic system on the water ecological civilization can be compared more reasonably (considering the availability of data, the farmland effective irrigation coefficient was not included in the water economic system when analyzing the situation of water ecological civilization in Jiangxi Province from 2011 to 2020). In the water social system, forest coverage rate and the number of national-level water conservancy scenic spots were added (the two indicators have not changed much in a short period of time and the availability of data is considered; therefore, they were not included in the water social system when analyzing the situation of water ecological civilization in Jiangxi Province from 2011 to 2020). We used the principal component analysis method to calculate the water ecological civilization of 11 prefecture-level cities in Jiangxi Province in 2020. The results are shown in Table 6. We can see that Ganzhou has the highest comprehensive score of water ecological civilization among 11 prefecture-level cities in Jiangxi Province in 2020, with a score of 1.7298, and Yingtan has the lowest score, with a score of −2.0697. The gap is significant, indicating that the development of water ecological civilization is not balanced among the various cities in Jiangxi Province.

Table 6. Water ecological civilization scores of prefecture-level cities in 2020.

Cities	Water Ecological Civilization	Ranking	Water Ecological System	Ranking	Water Economy System	Ranking	Water Social System	Ranking
Ganzhou	1.7298	1	2.6292	1	0.1922	5	0.8211	2
Shangrao	1.4924	2	1.7671	2	0.0891	6	0.7856	3
Yichun	1.3915	3	1.5490	3	0.7422	4	0.0737	7
Fuzhou	1.2120	4	1.0747	4	0.7942	3	0.6550	4
Ji'an	0.9596	5	1.0315	5	0.8993	2	0.6284	5
Jiujiang	0.6657	6	0.6873	6	1.0390	1	0.2217	6
Nanchang	−1.0709	7	−0.6471	7	−0.4243	8	−2.4479	11
Xinyu	−1.2038	8	−2.6595	11	−0.0856	7	−0.2027	8
Pingxiang	−1.4375	9	−1.6645	9	−0.5114	9	−0.4027	9
Jingdezhen	−1.6692	10	−1.6629	8	−1.4827	11	0.9066	1
Yingtan	−2.0697	11	−2.1049	10	−1.2519	10	−1.0387	10

First, from Table 6, we can see that Ganzhou ranks first, Shangrao second, and Yichun third in the score of water ecological system, but there is little difference between Shangrao and Yichun. In terms of the natural endowment of water resources, the annual precipitation in Ganzhou and Shangrao is higher than that in Yichun. The reason is that the annual precipitation in Ganzhou and Shangrao is relatively abundant, which provides innate conditions for the surface water resources and groundwater resources of the two cities. Therefore, the natural endowment of water resources in the two cities is better than that in Yichun; in terms of the development of water resources, Ganzhou and Shangrao have lower total water consumption than Yichun, but higher water consumption in the ecological environment than Yichun. The reason is that Ganzhou and Shangrao pay more attention to ecological environmental protection, which is similar to Ganzhou and Shangrao being rated as national forest cities. This is in line with Ganzhou and Shangrao being rated as national forest cities, so Ganzhou and Shangrao have better water resources development than Yichun, but in terms of sewage treatment capacity, Yichun is not only lower than Shangrao in terms of ammonia nitrogen emission of urban domestic sewage and chemical oxygen demand of urban domestic sewage, but also higher than Shangrao in terms of the number of wastewater treatment facilities and the treatment capacity of wastewater treatment facilities; this is the reason why there is little difference between Shangrao and Yichun.

Secondly, from Table 6, we can see that Jiujiang ranks first, Ji'an second, and Fuzhou third in the score of water economy system. In terms of water resource utilization efficiency, Jiujiang's average water consumption per mu for farmland irrigation, utilization rate of water resources, water consumption per 10,000 USD of added value of manufacturing, water consumption per 10,000 USD of GDP and per capita water consumption are all lower than the provincial average level. Jiujiang's farmland effective irrigation coefficient, sewage treatment rate, density of drainage pipeline, and water penetration rate are all higher than the provincial average level, especially the average water consumption per mu of farmland irrigation, the farmland effective irrigation coefficient, and the utilization rate of water resources are all the best in the province. These indicators together make Jiujiang ranked first in the water economic system; Nanchang's water consumption per 10,000 USD GDP is 339.29 $m^3/10^4$ \$, which is the best in the province. However, the average water consumption per mu of farmland irrigation and the utilization rate of water resources are higher than the average level of the province. Nanchang's utilization rate of water resources is the highest in the province, at 31.99%, which is much higher than the province's average level of 15.96%. These indicators together have lowered Nanchang's ranking in the water economy system. In terms of water management, Yingtan and Jingdezhen ranked as the last two, which were lower than the provincial average in the three indicators of proportion of investment in water-related affairs in general budget revenue, sewage treatment rate, and density of drainage pipe, resulting in the lower ranking of the two cities.

Third, from Table 6, we can see that Jingdezhen ranks first, Ganzhou second, and Shangrao third in the score of water social system, but the gap is not large. Jingdezhen has three national-level water conservancy scenic spots, which is lower than Ganzhou's six national-level water conservancy scenic spots, but its per capita park green space area and the green coverage rate of built-up areas are higher than Ganzhou. Shangrao has eight national-level water conservancy scenic spots and is the city with the largest number of national-level water conservancy scenic spots in Jiangxi Province. However, it's per capita park green space area is lower than that of Jingdezhen, and it's the green coverage rate of built-up areas and forest coverage rate are lower than those of Jingdezhen and Ganzhou, thus lowering the ranking. As the most economically developed city in Jiangxi Province, Nanchang has a score of -2.4479 in the water social system, ranking at the bottom. All four indicators in its water social system are lower than the provincial average.

Finally, from Table 6, it can be found that the comprehensive score ranking of water ecological civilization is basically the same as the score ranking of water ecological system, indicating that water ecology is the key to affecting water ecological civilization. Cities with richer natural endowments of water resources also rank high in the score of water ecological system, which indirectly indicates that there is a certain correlation between water ecological civilization and natural endowments of water resources. As for the top cities in the comprehensive score of water ecological civilization, the ranking of the water economy system score is opposite to that. The reason may be that these cities have caused certain damage to the ecological environment while improving water use efficiency and increasing investment in water conservancy projects, which affects the score of the water ecological system and indirectly affects the comprehensive score of water ecological civilization.

In order to more intuitively reflect the gap in the construction level of water ecological civilization in 11 prefecture-level cities in Jiangxi Province, we used the systematic clustering method to conduct cluster analysis on the comprehensive score of water ecological civilization, water ecological system score, water economic system score, and water social system score, and used ArcGIS 17.0 to draw the spatial pattern of water ecological civilization in Jiangxi Province in 2020, which are divided into three categories: high, medium, and low, and the colors are green, red, and yellow, respectively, as shown in Figure 3. The green areas include Ji'an, Fuzhou, Jiujiang, Yichun, Ganzhou, and Shangrao, the red areas only include Nanchang, while Pingxiang, Xinyu, Yingtan, and Jingdezhen belong to the yellow areas. It is found that the water ecological civilization in southern and central Jiangxi is generally higher than that in northern Jiangxi. The reason is that the annual precipitation in southern and central Jiangxi is rich, which provides innate advantages for surface water resources and groundwater resources, so that the total amount of water resources is higher than other regions, ensuring the safety of water for residents. At the same time, northern Jiangxi is an area with good economic growth in Jiangxi Province. However, due to the high proportion of low-end and middle-end industries in the industrial structure, the economic growth is mostly non-intensive growth, and there are high pollution, high consumption, and high discharge in the process of water utilization, resulting in a low level of water ecological civilization.

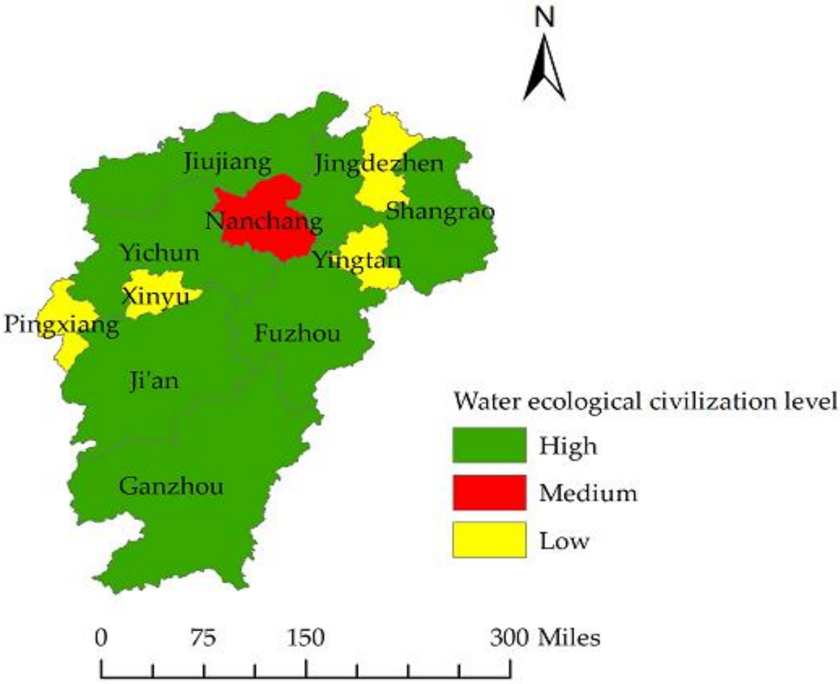

Figure 3. The spatial pattern of water ecological civilization in Jiangxi Province in 2020.

3.2. Regression Analysis

In order to avoid pseudo regression, IPS, fish ADF, and fish PP are used for unit root test. It is found that some variables do not significantly reject the original hypothesis, that is, there is a unit root, but the unit root test is carried out after the first-order difference; it is found that all variables reject the original hypothesis, and there is no unit root, that is, each variable is integrated of order one I(1). The results are shown in Table 7.

Table 7. Results of first-order unit root test.

Variables	IPS	Fish-ADF	Fish-PP
WE	−0.0037 *** (0.0012)	110.3339 *** (0.0000)	51.6325 *** (0.0004)
EG	−2.4808 *** (0.0066)	175.5379 *** (0.0000)	56.2524 *** (0.0001)
IN	−4.2913 *** (0.0000)	92.4279 *** (0.0000)	150.8276 *** (0.0000)
UR	−3.5780 *** (0.0002)	294.7002 *** (0.0000)	65.0310 *** (0.0000)
ED	−2.5044 *** (0.0061)	111.0114 *** (0.0000)	114.7665 *** (0.0000)
GI	−3.2240 *** (0.0006)	56.2410 *** (0.0001)	71.3105 *** (0.0000)
HJ	−3.1394 *** (0.0008)	89.4561 *** (0.0000)	43.5977 *** (0.0040)
UR^2	−4.4328 *** (0.0000)	390.5083 *** (0.0000)	88.8324 *** (0.0000)

Note: *** indicate that the variable is significant at the level of 1%.

Since the each variable is integrated of order one I(1), it is necessary to determine whether there is a long-term equilibrium relationship before regression, that is, to test whether there is a cointegration relationship between variables. In this paper, the Kao test, Pedroni test, and Westerlund test are selected for the cointegration test. The results show that the original hypothesis is rejected at the 1% significant level, indicating that there is a long-term equilibrium relationship between the variables, which can be estimated.

We first used mixed effect model, fixed effect model, and random effect model to estimate, and conducted the F test, LM test, and Huasman test on model (1), respectively. The results show that the former two reject the original hypothesis, so we choose the individual fixed effect model and random effect model. The p value of the modified Huasman test is 0.0000, rejecting the original hypothesis, so the individual fixed effect model is finally selected for estimation [41], and the results are shown in Table 8.

Table 8. Regression results.

	Fixed Effect Model	Random Effect Model	Mixed Effect Model
cons	−0.778 * (−1.815)	−1.249 * (−1.736)	−1.878 * (−1.794)
EG	2.390 (1.412)	2.221 ** (2.034)	4.394 * (1.735)
IN	0.293 *** (3.741)	0.416 * (1.757)	0.458 * (1.872)
UR	1.883 * (1.794)	2.372 * (1.730)	3.107 * (1.749)
ED	2.164 * (1.863)	3.484 * (1.699)	5.570 * (1.722)
GI	1.424 * (1.795)	2.061 * (1.778)	2.278 * (1.856)
HJ	−0.201 **(−2.074)	−0.207 * (−1.842)	−0.193 * (−1.763)
UR^2	−1.828 * (−1.763)	−2.399 * (−1.854)	−3.382 * (−1.776)
Adjust-R^2	0.621	0.595	0.614
Test	F test (p = 0.000)	LM test (p = 0.000)	
Huasman test		p = 0.000	

Note: *, ** and *** indicate that the variable is significant at the level of 10%, 5% and 1% respectively.

From Table 8, we can see that the estimated coefficient of economic growth is positive, but it has not passed the significance test. The reason may be that the quality of economic growth is gradually improving in the process of economic development in Jiangxi Province, but the economic growth mode has not undergone a fundamental change, and it is in the process of transforming from extensive to intensive. Therefore, economic growth is conducive to the restoration of the water ecological environment, which improved the score of water ecological civilization, but it has not passed the significance test. Accordingly, Jiangxi's economic growth needs to accelerate the transformation to an intensive economic growth mode and pay more attention to water ecological benefits and water environment protection. The estimated coefficient of the industrial structure is 0.293, which is significant at the 1% level. The reason is that Jiangxi is changing from low-end industries dominated by labor-intensive and low value-added industries to high-end industries dominated by capital, technology, knowledge-intensive, and high value-added industries. Most of these industries are resource-saving and environment-friendly industries, which help to improve the utilization efficiency of green water resources and reduce wastewater discharge, so as to improve the score of water ecological civilization. The estimated coefficient of educational investment is 2.164, which is significant at the 10% level. It shows that increasing investment in education and improving the quality of the population is conducive to improving the public's awareness of water ecological environmental protection, saving water resources, accelerating the research, and development of green water utilization technologies, and improving the level of water ecological civilization. The regression coefficient of the government governance level is 1.424, and it is significant at the 10% level. The reason is that the government departments control and punish enterprises that damage the water ecological environment according to their functions, and provide financial subsidies, tax relief, and loan offers to environment-friendly enterprises; encourage enterprises to fulfill their social responsibilities in treating wastewater and protecting the water environment; and increase the enthusiasm for reused and recycled water, so as to improve the score of water ecological civilization.

From Table 8, we can also see that the estimated coefficients of the urbanization level and its square term are 1.883 and −1.828, respectively, and are significant at the 10% level, indicating that there is an inverted U-shaped curve between the urbanization level and water ecological civilization. When the urbanization rate is lower than a certain critical point, the urbanization level is conducive to the improvement of water ecological civilization score. At this time, the utilization rate of water resources, groundwater exploitation coefficient, sewage discharge, etc. are at reasonable values, which are within the bearing range of the water ecological environment. At the same time, the population transfer in the process of urbanization is the driving force, which is conducive to improving the water efficiency. When the urbanization level exceeds the critical value, the increase of urbanization rate is not conducive to the improvement of the water ecological civilization score. The reason may be that with the acceleration of the urbanization process, a large amount of infrastructure construction and real estate construction consumes too much water resources. At the same time, too many surplus rural laborers have been transferred to urban areas for employment, resulting in huge population pressure, which increases the domestic water consumption of residents. Most rural laborers have entered labor-intensive and high-water-consuming industries with a low technical level, which increases the industrial water consumption. The estimated coefficient of environmental pollution is −0.201, and it is significant at the 5% level, indicating that the aggravation of environmental pollution has led to a continuous increase in the negative effect of the water ecological environment, which is not conducive to the improvement of the water ecological civilization score.

To test the robustness of the above results, first, we remeasured the independent variables. GDP and non-agricultural industry output value/GDP were used to remeasure economic growth and industrial structure for empirical estimation, respectively. The regression results are shown in Table 9. Secondly, the system GMM (Generalized Method of Moments) was used to estimate the model, we selected the independent variable lagged by two periods as the instrumental variable, and then reliable regression results were obtained. The regression results are shown in Table 10. Tables 9 and 10 show that the size and significance level of the estimated coefficients of the economic growth, industrial structure, education investment, government governance level, urbanization level, and environmental pollution on the water ecological civilization have remained more or less the same; there is no substantial change. Thus, this study passes the robustness test.

Table 9. Results of robustness test (1).

	Fixed Effect Model	**Random Effect Model**	**Mixed Effect Model**
cons	−0.807 * (−1.746)	−1.619 * (−1.724)	−2.065 * (−1.832)
EG	2.347 (1.509)	3.115 * (1.702)	2.684 * (1.698)
IN	0.287 *** (3.643)	0.398 ** (2.023)	0.360 * (1.757)
UR	1.856 ** (2.001)	2.141 * (1.804)	2.838 * (1.715)
ED	1.982 * (1.790)	2.927 * (1.801)	3.619 ** (2.043)
GI	1.508 ** (2.026)	1.850 ** (2.106)	2.002 * (1.790)
HJ	−0.189 * (−1.753)	−0.213 * (−1.817)	−0.174 * (−1.801)
UR^2	−1.911 * (−1.824)	−2.056 ** (−2.012)	−2.393 * (−1.726)
Adjust-R^2	0.607	0.586	0.598
Test	F test (p = 0.000)	LM test (p = 0.000)	
Huasman test		p = 0.000	

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

Table 10. Results of robustness test (2).

Variable	Coefficient	*p* Value
cons	2.189 **	0.047
EG	2.428	0.163
IN	0.266 ***	0.009
UR	1.971 **	0.030
ED	1.863 *	0.074
GI	1.604 *	0.081
HJ	−0.175 **	0.036
UR^2	−1.807 *	0.093
Wald test	993.371	
Sargan test	0.220	
Arellano-Bond AR (1)	0.005	
Arellano-Bond AR (2)	0.224	

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

3.3. Discussion

First, we find that the level of water ecological civilization in Jiangxi Province shows a fluctuating upward trend; there are significant differences in the level of water ecological civilization in different cities in Jiangxi Province. This result is consistent with the uneven spatial distribution of water resources in different cities in Jiangxi Province. Among the 11 prefecture-level cities, Ji'an, Fuzhou, Jiujiang, Yichun, Ganzhou, and Shangrao have abundant annual precipitation, and their water ecological civilization is also relatively high, while Pingxiang, Xinyu, Yingtan, and Jingdezhen have less annual precipitation, and their water ecological civilization is also low. The result confirmed that the uneven spatial distribution of water resources affects the water ecological environment and water ecological civilization. Moreover, this result is similar to the studies by Deng et al. and Su et al. on the development level of China's water ecological civilization [42,43]. The former found that the level of China's water ecological civilization construction continued to improve from 2010 to 2016, and the gap of the level of 31 provinces is significant and not narrowing. The latter found that the development index of China's water ecological civilization is increasing year by year, and there are significant regional differences, showing a pattern of "high-low-medium" from east to west.

Secondly, based on the panel data of prefecture-level cities in Jiangxi Province from 2011 to 2020, the panel data model is used to empirically analyze the impact factors of water ecological civilization. We find that the positive effect of economic growth on the level of water ecological civilization has not passed the significance test. Industrial structure, educational investment and government governance level have significantly improved the level of water ecological civilization. Environmental pollution is not conducive to improving the level of water ecological civilization. There is an inverted U curve between urbanization level and the level of water ecological civilization. Darko et al., Kan et al., and Margaret et al. believe that the effects of urbanization, such as population upsurge, increased industrialization, urban agriculture, and rural–urban migration of persons exert pressure on the limited water resources in most cities; the urbanization process has a negative impact on the overall quality of the water ecological environment, which not only intensifies the emission of water environmental pollution, but also inhibits the water environmental absorption capacity [44–46]. The regression results are similar to those of Al-Mulali et al. and Irfan and Shaw on the relationship between new-type urbanization and ecological environment in 93 countries and South Asian countries, respectively [47,48], but they are inconsistent with the results of Li on the relationship between new-type urbanization and ecological environment; he found an anti-N-shaped relationship between urbanization and ecological environment in China [49]. In short, the empirical results confirmed the expectations in the model construction.

On the basis of the existing study on evaluating water ecological civilization, this study improves the analysis of the impact factors of water ecological civilization, enriches the theory of ecological civilization, and improves the research content of sustainable development theory. This study also provides a reference for other developing countries similar to China on how to improve the water ecological environment in the process of economic development. However, this study also has research limitations. Considering the availability of data, the evaluation indicator system of water ecological civilization does not include water culture system. Further, the analysis of the impact factors of water ecological civilization is not comprehensive enough. Therefore, the further research direction in the future is to obtain the data of various indicators of water culture system through investigation, comprehensively construct the evaluation indicator system of water ecological civilization, improve the theoretical analysis of the impact factors of water ecological civilization, and empirically study the impact factors of water ecological civilization by taking other countries as objects.

4. Conclusions

According to the above results and the actual development of Jiangxi Province, in order to further promote the level of water ecological civilization, this paper will put forward the following suggestions:

First of all, in terms of water ecology, the prefecture-level cities in Jiangxi need to coordinate with each other, exert the "neighborhood" effect, eliminate regional administrative barriers, and establish a long-term and effective water rights trading system between regions. At the same time, it is necessary to strengthen the construction of rainwater collection facilities, improve the utilization rate of unconventional water, and reduce the exploitation of groundwater. It is necessary to optimize the industrial structure; comprehensively investigate the enterprises with heavy pollution, high consumption, and high emission; and provide policy support and tax relief to urge them to adjust the product structure and encourage the development of resource-saving and environment-friendly enterprises. We should increase capital investment in the environmental protection industry; speed up water ecological restoration and water environment pollution control, while improving sewage treatment efficiency; strictly set up water ecological protection red lines; strengthen law enforcement supervision of the implementation of red line management; and further improve the water ecological protection compensation mechanism, improve the utilization efficiency of green water resources, and strengthen the construction of water ecological civilization.

Secondly, in terms of water economy, Jiangxi needs to actively implement the innovation-driven strategy, encourage scientific and technological innovation, and improve water use efficiency. The government needs to work with research institutes and universities to build a high-level scientific research platform, improve technology transformation capabilities, reduce water consumption per unit of output value, and improve economic benefits. Jiangxi needs to promote large-scale agricultural planting and water-saving irrigation technology, improve agricultural water use efficiency, alleviate water use conflicts, and give preferential tax policies to agricultural enterprises that use high-efficiency water-saving technology; Jiangxi needs to use new media as a carrier to promote water-saving culture, advocate water conservation, cultivate national water conservation awareness, and speed up the construction of a water-saving society; Jiangxi also needs to increase capital investment in water-related facilities and improve the recovery rate of residential water.

Third, in terms of water society, Jiangxi needs to improve and strictly implement environmental regulations related to the water ecological environment according to local conditions, and at the same time, increase the intensity of artificial afforestation, improve the forest coverage rate, and enhance the function of water and soil conservation. Some areas in Jiangxi can adopt the new model of "water conservancy scenic area + eco-tourism", using unique water conservancy functions and natural scenery, so that tourists can have an in-depth understanding of water culture, water landscape, and water ecological civilization, so that social and economic benefits can be effectively combined.

Finally, all prefecture-level cities in Jiangxi Province need to implement new development concepts and innovation-driven strategy, make up for shortcomings, and strengthen weak points according to their own natural endowments of water resources. It is necessary to further optimize the industrial structure, increase investment in education, improve the level of government governance, strengthen the construction of urbanization connotation, and improve the level of water ecological civilization, especially to abandon the extensive urbanization development model, pay attention to the improvement of urbanization quality in the process of promoting the development of new-type urbanization, and realize the harmonious coexistence of people and water.

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