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Comparative Analysis of the Evolutionary Characteristics and Influencing Factors of Land and Water Resource Systems in Major Grain-Producing Areas

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Abstract: In the process of rapid advancement of agricultural production, the dynamic evolution characteristics of land and water resources in the main grain-producing areas and the influencing factors are less studied. This study takes Heilongjiang Province, the main grain-producing area in China, as an example, constructs an index system from three functions: production, life, and ecology, uses information entropy to determine the weights and importance of each index, uses the rate of change of the index to determine the basic data of the dynamic development of the system, combines the weights to determine the dynamic evolution characteristics, and compares and analyzes them with the static evolution characteristics determined by the actual data. The results showed that there were differences in the important indicators under different conditions, and the important indicators under static and dynamic conditions were the proportion of the tertiary industry to GDP(A7) and GDP per unit area(A8), with importance weights of 7.45% and 8.0%, respectively. The static evolution index of the land and water resource system increased slowly from 0.16 to 0.91, while the dynamic evolution index fluctuated and declined from 0.58 to 0.34, indicating that the ability of the land and water resource system in the study area to maximize comprehensive benefits is constantly weakening. Managers can pre-control the development speed of the important indicators under dynamic conditions and promote the sustainable development of the land and water resource system.

Keywords: land and water resource system; rate of change; evolutionary index; influencing factors; comparative analysis

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1. Introduction

Among the 17 sustainable development goals (SDGs) proposed by the United Nations in 2015, agriculture and food systems occupy eight [1]. It is evident that agriculture has become a key link in the sustainable development of human society. With the substantial increase in grain production in China, problems such as low utilization of water resources [2], serious pollution of land and water resources [3], and food safety caused by agricultural environmental pollution have arisen in agricultural production [4], so there is a need for rational planning and management of soil and water resource systems in major grain-producing areas.

As a collection of natural resources, land and water resources are essential resources for agricultural production. To improve the efficiency of agricultural land and water resource utilization to guarantee food security, scholars are currently conducting scientific research on land and water resource development and utilization [5], optimal management of land and water resources [6], and risk prevention [7], mainly from the actual data of land and water resource systems.

In terms of the development and utilization of land and water resources, the construction of an indicator system is still the main focus, and research is being conducted on the effective evaluation of land and water resources. Cheng et al. objectively analyzed the carrying capacity of land and water resources as well as the main influencing factors in the main grain-producing areas by using a cloud model that converts between qualitative and quantitative analyses [8,9]. Tan et al. assessed the carrying capacity of land and water resources in all Chinese provinces from 2009–2017 by constructing a DPSIR model [10]. Wen et al. conducted quantitative research on the spatiotemporal dynamic changes of the carrying capacity of land and water resources in grain-producing areas from four aspects based on the entropy weight-TOPSIS model [11]. Wang et al. conducted a comprehensive assessment of regional resource sustainability development by applying the newly established relative resource carrying capacity method, which considers population size and economic scale as resource carrying capacity [12]. He and Wang, based on ecological footprint theory, constructed the evaluation framework of the trend of soil and water resource carrying capacity changes from two perspectives on soil and water resource support and pressure [13].

In terms of optimizing the management of land and water resources, which started in the 1940s, Masse's reservoir optimization scheduling theory was developed [14]. Singh et al.'s linear programming model was used to manage land and water resources to achieve the maximization of output and revenue [15]. Subsequently, due to the multiple uncertainties in agricultural production, mathematical models, such as dynamic programming, stochastic programming, and fuzzy mathematics, have been widely applied to the management of land and water resources [16]. After the continuous improvement of information technology and remote sensing technology [17], these technologies have also been widely applied to the optimization management of land and water resources. With the development of computer technology and in-depth interdisciplinary research, Koven et al. combined the atmospheric simulation model and the ecological simulation model to explore the impact of climate change on water quantity, water quality, and ecology [18]. Yan et al. explored the matching pattern of crop and agricultural land and water resources under future climate change conditions [19]. Li et al. conducted a study on the optimal allocation of agricultural land and water resources in terms of agricultural water resources, energy, and food production under changing environmental conditions [20]. These studies have gradually brought the optimal management of land and water resources to a more mature stage.

As for the risk analysis of land and water resources, since the development and utilization of land and water resources have negative impacts on the environment and the vulnerability of land and water resources themselves [21], the risk analysis of land and water resources aims to quantify and evaluate the possible impacts and losses of the utilization of land and water resources on the environment [22]. In the assessment of water environments, the health-risk assessment model recommended by the US Environmental Protection Agency (EPA) is mainly adopted [23]. The sampling distribution theory and Bayesian inference theory are often used to address the uncertainty issues in risk assessment [24,25]. In terms of the risk assessment of the water quantity population, mathematical statistics and simulation methods, such as system dynamics, are mainly used [26,27]. In the risk assessment of land use, cloud models and landscape models combining fuzziness and uncertainty are mainly used [28]. In the risk analysis of land pollution, quantitative evaluation methods based on ecological footprint, mathematical models, and value accounting [29,30] are used with remote sensing, MapGIS, and other technologies for comprehensive evaluation and management [31,32]. Therefore, the rapidly changing scientific and technological advancements provide favorable tools for scientific research on land and water resources.

Overall, in the evaluation and management of land and water resources, research on environmental changes such as global population expansion, temperature rise, and ecological degradation has become the main direction at present, and research methods and perspectives are continuously enriched and improved. However, there is a lack of research on the dynamic evolution of land and water resources under changing environments and the influencing factors, which makes it difficult to realize the advanced planning of optimal management of land and water resources. In this paper, Heilongjiang province, a major grain-producing region in China, was selected as the study area, and the period from 2004 to 2020 was used as the study period, during which agricultural water use and arable land area continued to grow, and grain production increased rapidly. It constructs an indicator system based on the "Production–Life–Ecology" function of land and water resources, determines the indicator weights by using the information entropy theory, which has the ability to measure uncertain information, and determines the dynamic development index of each indicator by the rate of change. We compare the static development indices determined from the raw data of each indicator, and analyze the evolution trends and influencing factors of land and water resource systems in Heilongjiang Province under dynamic and static conditions, and provide new ideas and reference bases for the advance planning and management of regional land and water resources.

2. Research Area

The study area, Heilongjiang Province, is located in an alpine region with a long winter time span and geographical coordinates: 121°11′~135°05′ E and 43°25′~53°33′ N, see Figure 1. As one of the important commodity grain bases in China, its grain production has been growing continuously since 2003 and will increase nearly threefold to 7.54×10^7 tons in 2020. At the same time, agricultural water consumption and arable land area also continued to grow, increasing by 1.85 times and 1.74 times, respectively, at the peak. Although the water consumption of CNY 10,000 output value fell by 3.99×10^2 m^3, it was still nearly four times higher than the national data of the same period, and the water use efficiency was relatively low. The per capita cultivated land area of the province increased from 0.26 hm^2 in 2003 to 0.54 hm^2. Although the converted fertilizer use started to show a downward trend in 2015, it increased from 1.26×10^6 tons in 2003 to 2.24×10^6 tons in 2020, with an increase of 77.78%. Therefore, it is necessary to conduct research on the evolutionary trends and influencing factors of regional soil and water resource systems.

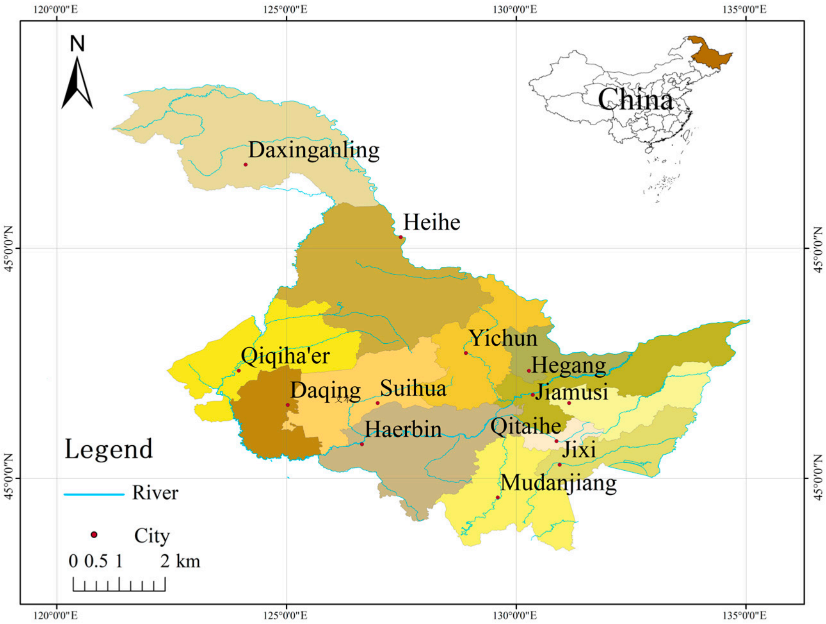

Figure 1. Geographical location of the study area.

3. Research Methods

3.1. Constructing Indicator System

The establishment of the indicator system of the land and water resource system is the basis and prerequisite for analyzing the evolution trend, and also the main basis for determining the influencing factors [33]. In this paper, we observe the basic principles of data accessibility, objectivity, and overall operability of the indicator system [34]. The index system is constructed with the objective of analyzing the impact of the land and water resource system on the sustainable development of the region, starting from the "Production–Life–Ecology" functions of reflecting the production capacity, livelihood protection, and ecological maintenance of land and water resources [35,36] (See Table 1). Among them, the production capacity is the ability to support agricultural and non-agricultural production and economic development, which is the fundamental driving force for the change of livelihood and ecological functions; the livelihood protection is the ability to guarantee regional life and social development, which is the fundamental purpose of production and ecological functions; the ecological maintenance is the ability to maintain and protect the ecological environment, which is the important environmental resources guarantee for the development of production and life functions. The disorderly or vicious development of one type of function among the "Production–Life–Ecology" functions will directly affect the coordinated development of the other functions. Only the coordinated and common development of the "Production–Life–Ecology" functions can promote the maximization of the comprehensive benefits of regional land and water resources and the sustainable development of the land and water resource system [37].

Table 1. Index system of water and land resources' "Production–Life–Ecology" functions.

Guideline Layer	Indicator Layer	Unit	Indicator Description	Indicator Meaning	Property
Production function	Effective irrigation rate (A1)	%	Effective irrigated area/Cultivated area	Agricultural production level	+
	Water consumption per unit of output value (A2)	m^3/yuan	Total water consumption/Total output	The level of water resources to support the economy	–
	Water consumption per unit of arable land (A3)	10^4 m^3/hm^2	Agricultural water consumption/Arable land area	The level of water resources to support agriculture production	–
	Secondary industry water consumption (A4)	m^3/yuan	Industrial water consumption/Industrial output	Level of water resources support for non-agricultural production	–
	Reclamation rate (A5)	%	Arable land area/Total land area	Agricultural production capacity carried by the land	+
	Grain yield per unit area (A6)	t/hm^2	Total food production/Arable land area	Level of agricultural production made of land	+
	The proportion of tertiary industry in GDP (A7)	%	Tertiary industry output/Total output	Non-agricultural production levels	+
	GDP per unit area (A8)	10^4 yuan/hm^2	Total production value/Total land area	Land supports the level of economic development	+
Life function	Water resources per capita (B1)	10^4 m^3/people	Total water resources/Total population	The ability of water resources to support livelihood standards	+
	Domestic water per capita (B2)	10^4 m^3/people	Domestic water consumption/Total population	Livelihood standards guaranteed by water resources	+
	Traffic density (B3)	%	Transportation land/Total land area	The ability of land resources to support livelihood standards	+

Table 1. *Cont.*

Guideline Layer	Indicator Layer	Unit	Indicator Description	Indicator Meaning	Property
Life function	Food production per capita (B4)	t/people	Total food production/Total population	Social level guaranteed by land resources	+
	Urban land density (B5)	%	Urban land area/Total land area	The level of social development supported by land	+
	Urbanization level (B6)	%	Urban population/Total population	Social development Level	+
	Population density (B7)	people/hm^2	Total population/Total land area	The ability of land to secure a standard of livelihood	+
Ecology function	Forest coverage rate (C1)	%	Forest area/Total land area	The ability of land and water resources to maintain the ecosystem	+
	Proportion of water for ecological environment (C2)	%	Ecological water use/Total water use	The ability of water resources to maintain the ecosystem	+
	Unit area of chemical fertilizer and pesticide film use (C3)	t/hm^2	(Fertilizer use + Pesticide use + Film use)/Cultivated land area	The level of land resources carrying ecological risks	−
	Sewage treatment rate (C4)	%	Wastewater treatment volume/Total discharge volume	The level of water resources carrying ecological risks	+
	SO_2 emissions per unit area (C5)	t/km^2	SO_2 Emissions/Town area	Ecological risk level	−
	Proportion of environmental investment (C6)	%	Total investment in environmental governance/GDP	The level of protection of the ecological environment	+

Notes: "+" are positive indicators; "−" are negative indicators; they indicate, respectively, relationship between numerical size and promotion of coordinated and sustainable development of land and water resources.

3.2. Determination of Indicator Weights

For this paper, the selected data are statistical data, and there are many uncertainties in the process of obtaining statistical data; the advanced theoretical information entropy [38,39], which quantifies the uncertainty information, is used to determine the weights of evaluation indices. Based on the degree of influence of the relative changes of index data on the system as a whole, the key indicators in determining the sustainable development of the land and water resource system are searched for, so that the evaluation of the evolution characteristics of the land and water resource system and the analysis of the main influencing factors can be carried out. The calculation steps are as follows:

Step 1: Standardization of metrics

Suppose the sample set is $\left\{x^*_{ij} | i = 1, 2, \ldots, q; j = 1, 2, \ldots p\right\}$, where x^*_{ij} is the value of the i indicator in j year, and q, p are the number of indicators and the length of the time series, respectively.

$$\text{Positive indicators}: \; x'_{i,j} = \frac{x^*_{ij} - x_{\min}(i)}{x_{\max}(i) - x_{\min}(i)} \tag{1}$$

$$\text{Negative indicators}: \; x'_{i,j} = \frac{x_{\max}(i) - x^*_{ij}}{x_{\max}(i) - x_{\min}(i)} \tag{2}$$

In the above equation, $x_{\max}(i)$ and $x_{\min}(i)$ denote the maximum and minimum values of the indicator i, respectively, and $x'_{i,j}$ is the standardized index value.

Step 2: Calculate the entropy value of each indicator

According to the information entropy theory, the entropy value of each index is determined.

$$E_i = -\frac{1}{\log p} \sum_{j=1}^{p} x_{ij} \log x_{ij} \tag{3}$$

$$x_{ij} = \frac{1 + x'_{i,j}}{\sum\limits_{j=1}^{p} (1 + x'_{i,j})} \tag{4}$$

In the above equation, E_i is the entropy value of indicator i.

Step 3: Calculate the indicator weights

The greater the information entropy value of each indicator, the smaller the effect on the soil and water resource system, based on this to determine the weights.

$$d_i = \frac{1 - E_i}{q - \sum\limits_{i=1}^{q} E_i} \tag{5}$$

In the above equation, d_i is the weight of indicator i.

3.3. Identification of Trends in the Evolution of Land and Water Resource Systems

During the study period, there were large differences in the development rate of each indicator, which had a large impact on the development trend of the soil and water resource system in the study area. In this paper, the actual data of each indicator are used to determine the static evolution index of the soil and water resource system, which reflects the current status of the development and utilization of the soil and water resource system under a certain time section. The rate of change derived from the actual data determines the dynamic evolution index of the soil and water resource system, reflecting the development rate of each indicator of the soil and water resource system under changing conditions. The details are as follows:

The static evolution index is determined by normalizing the actual data of each indicator and combining the weights of the indicators (see Equation (6)).

The dynamic evolution index is based on the actual discrete data of each indicator, and the development function of the indicator ($f_i(x)$) is derived using the Fourier series and Gaussian series to fitting functions (see Equation (9)), and the rate of change of the development function is used to determine the development rate function of each indicator ($V_i(x)$). The time series of the study period 2005–2019 was used as the independent variable to obtain the rate of change of each indicator at different times as the base data under dynamic conditions. Combined with the calculation method of indicator weights, the weights of the indicators under dynamic conditions (d'_i) are obtained, and then the dynamic evolution index of the soil and water resource system is determined (see Equation (7)).

Static Evolution Index:

$$ST_j = \sum_{i=1}^{q} d_i x'_{i,j} \tag{6}$$

Dynamic Evolution Index:

$$DT_j = \sum_{i=1}^{q} d'_i \quad V_i(x)\big|_{x=j} \tag{7}$$

$$V_i(x) = df_i(x)/dx \tag{8}$$

Fourier series fitting:

$$f_i(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos(n\omega x_i^*(j)) + b_n \sin(n\omega x_i^*(j))) \tag{9}$$

Gaussian series fitting:

$$f_i(x) = \sum_{n=1}^{\infty} a_n e^{-\left(\frac{x_i^*(j) - b_n}{c_n}\right)^2} \tag{10}$$

$$R^2 = 1 - \frac{\sum\limits_{j=2004}^{2020} (x_i^*(j) - f_i(x)\big|_{x=j})^2}{\sum\limits_{j=2004}^{2020} (x_i^*(j) - \overline{x_i^*(j)})^2} \tag{11}$$

$$RMSE = \sqrt{\frac{1}{p} \sum_{j=2004}^{2020} (x_i^*(j) - f_i(x)\big|_{x=j})^2} \tag{12}$$

In the above equation, $f_i(x)$ is the development function of the indicator i, $V_i(x)$ is the rate of change of indicator i, $d\ _i'$ are the dynamic indicator weights, $V_i(x)\big|_{x=j}$ is the base datum of the indicator i in the year j under dynamic conditions, n in the fit function is determined by R^2, $RMSE$.

3.4. Data Sources

Based on the actual data of each indicator in the study area from 2004 to 2020, this paper determines the weights of each indicator to analyze the main influencing factors and conducts a comprehensive evaluation of the evolution trend. The data involved in the transportation land are the total length of roads and railway lines, the total investment in environmental management and the total amount of emissions are from the China Statistical Yearbook on Environment (2004–2020), the forest area is from the China Statistical Yearbook (2004–2020), the urban land area is from the China Urban Construction Statistical Yearbook (2005–2020), and other original data are from the Heilongjiang Statistical Yearbook (2004–2020), with some missing data supplemented by interpolation.

4. Results Analysis and Discussion

4.1. Comparative Analysis of Factors Influencing Land and Water Resource Systems under Different Conditions

Determine the importance of each indicator by weight calculation method and screen out the main factors, which will affect the comprehensive benefits of land and water resources. The actual discrete data of each indicator are brought directly into the Equations (1) to (5) to determine the static importance of each indicator (d_i). The basic data of each indicator under dynamic conditions are brought into Equations (1) to (5) to obtain the dynamic importance of each indicator (d_i), see Figure 2.

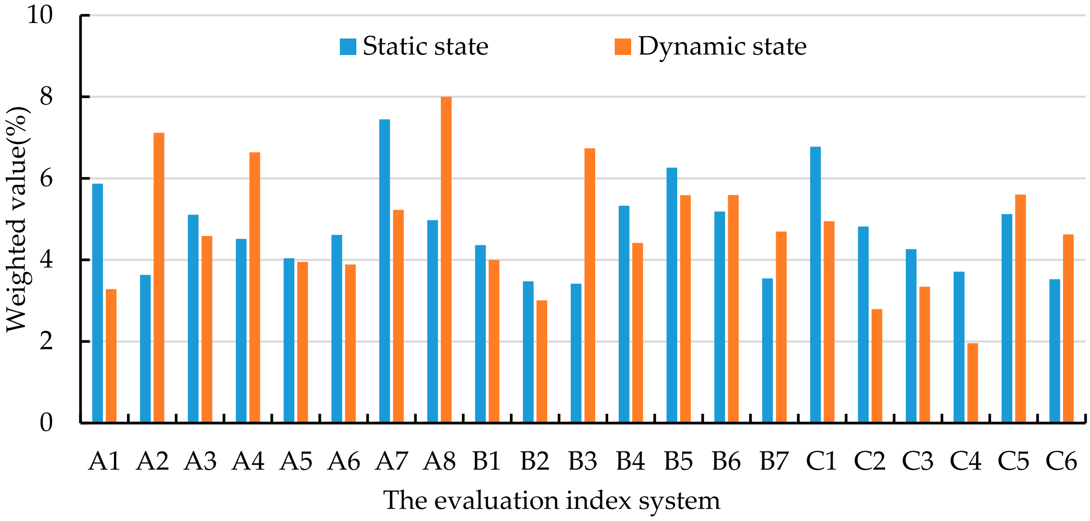

Figure 2. Comparison of the importance of each index under different conditions.

As shown in Figure 2, there are five indicators of the production function of land and water resources that vary greatly in importance under different conditions. They are effective irrigation rate (A1), water consumption per unit of output value (A2), secondary industry water consumption (A4), the proportion of tertiary industry in GDP (A7) and GDP per unit area (A8), and the differences in importance are above 2%, while the differences in importance of other indicators are below 1%. Under different conditions, the proportion of tertiary industry in GDP (A7) is a statically important indicator (indicator importance of 7.45%), the GDP per unit area (A8) is a dynamically important indicator (indicator importance of 8.00%), and under dynamic conditions, the indicator importance of water consumption per unit of output value (A2) also reaches over 7%, which is a very important indicator. It means that the proportion of tertiary industry in GDP (A7) and GDP per unit area (A8) are the fundamental drivers of changes in livelihood and ecological functions of land and water resources in static and dynamic development, and their indicator meanings are the level of non-agricultural production and the ability of the land to support economic development, respectively. Here, there are differences in the production functions of the important indicators under different conditions.

The importance differences of seven indicators in the life function are small under different conditions, and only the importance difference of traffic density (B3) reaches 3.32%. In addition, the difference in importance of population density (B7) is 1.15% under different conditions, and the difference in importance of other indicators is less than 1%. Under different conditions, urban land density (B5) is a statically important indicator (index importance of 6.26%) and traffic density (B3) is a dynamically important indicator (index importance of 6.74%). It indicates that regardless of the development in that condition, concerning the production and ecological functions of land and water resources, their main purpose is to promote the carrying capacity of land and water resources for social development and life, and there is very little difference in important indicators under different conditions.

Among the ecological functions, the proportion of water for the ecological environment (C2) has the largest importance difference of 2.02% under different conditions. In addition, the forest coverage rate (C1), sewage treatment rate (C4), and proportion of environmental investment (C6) differed by more than 1% under different conditions, while the importance of other indicators differed by less than 1%. Under different conditions, forest coverage rate (C1) is a static important indicator (indicator importance is 6.78%), and SO_2 emission per unit area (C5) has an importance of 5.12%, which is the main indicator under static conditions. Meanwhile, SO_2 emission per unit area (C5) is an important indicator in dynamic conditions (indicator importance of 5.60%), while forest coverage rate (C1) is another major indicator in dynamic development (indicator importance of 4.95%). It indicates that forest coverage rate and SO_2 emission per unit area are important indicators of ecology functions regardless of development under any conditions. The meanings of these two indicators, which are the ability to maintain the ecological environment and the degree of ecological risk, directly affect the ability of land and water resources to provide security for production and life.

4.2. Characterization of the Evolution of Land and Water Resource Systems under Different Conditions

The actual data of each indicator in the study area from 2004 to 2020 were substituted into Equations (1) to (6) to determine the static evolution index of the "Production–Life–Ecology" functions of land and water resources (see Figure 3). Substitute the actual data of each indicator into Equations (9) to (12); the fitting functions of each index were selected by $R^2 \to 1$ and $RMSE \to 0$ and implemented by Python, in which water consumption per unit of arable land (A3), reclamation rate (A5), water resources per capita (B1), fertilizer and pesticide film use per land (C3), and sewage treatment rate (C4) were fitted by Gaussian series, and all other indices were fitted by Fourier series. Considering that 2004 and 2020 are the time boundaries of this study, which has uncertainty, this paper only selects the change rate of each indicator in the study area from 2005 to 2019 as the initial data under dynamic conditions, and in combination with Equations (1) to (5) and Equations (7) to (8), the dynamic evolution index of the "Production–Life–Ecology" functions of land and water resources is determined (see Figure 4).

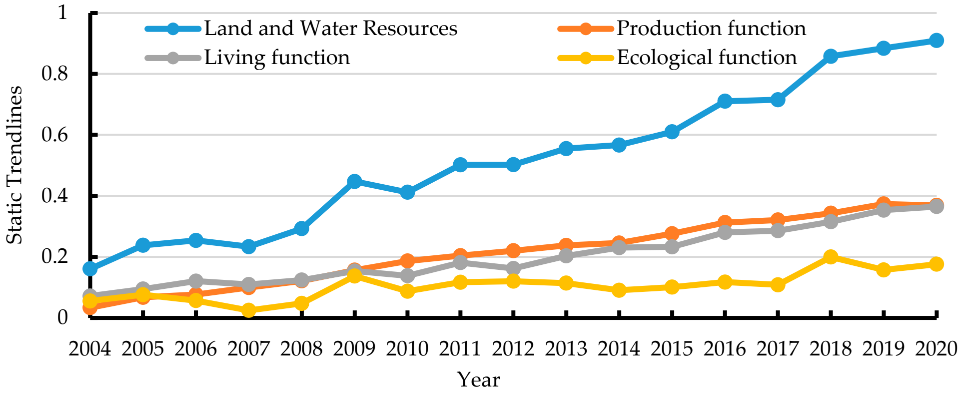

Figure 3. Static evolution trend of the "Production–Life–Ecology" functions of land and water resources.

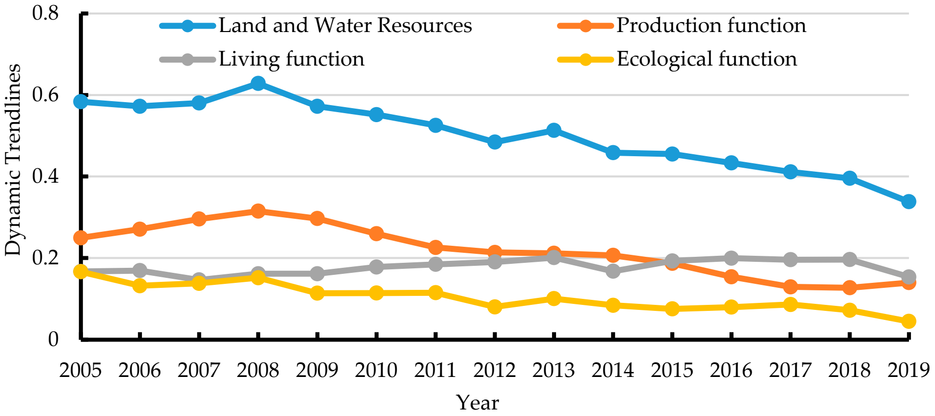

Figure 4. Dynamic evolution trend of the "Production–Life–Ecology" functions of land and water resources.

4.2.1. Static Evolution Index of "Production–Life–Ecology" Functions of Land and Water Resources

The static evolution time series diagram of the "Production–Life–Ecology" functions of land and water resources shows that the "Production–Life–Ecology" functions basically show a slow growth trend. The static evolution index of the production function increased continuously from 0.034 in 2004 to 0.37 in 2019, with a short decline in 2020, which is the largest index change among the land and water resource criterion layer, with a range of 0.34. The static evolution index of the life function increased continuously from 0.072 in 2004 to 0.36 in 2020, which is the largest index change among the land and water resource criterion layer, with a range of 0.29. The static evolution index of ecology function has a minimum of 0.025 in 2007 and a maximum of 0.20 in 2018 with some fluctuation, but it is the least variable index among the land and water resource criterion layer, with a range of 0.16.

The share of tertiary sector in GDP (A7), an important indicator of production function, changed by 0.67 during the study period, while the GDP per unit area (A8), as the fourth most important indicator, changed by 2.28. The urban land density (B5), as an important indicator of the life function, changed by 0.32 during the study period, while the amount of water resources per capita (B1), the fourth most important indicator, changed by 2.84. Forest coverage rate (C1) and SO_2 emission per unit area (C5), as important indicators of ecology functions, varied by 0.11 and 0.85, respectively, during the study period, while sewage treatment rate (C4), which ranked fifth in terms of importance, varied by 30.79. It can be seen that under static conditions, there is a large difference between indicators that actually varies a lot among those that are important.

4.2.2. Dynamic Evolution Index of the "Production–Life–Ecology" Functions of Land and Water Resources

From the dynamic evolution of the "Production–Life–Ecology" functions of land and water resources, we can see that the "Production–Life–Ecology" functions basically show a fluctuating downward trend. The dynamic evolution index of the production function fluctuates up from 2005 to 0.32 in 2008 and continues to decline to 0.13 in 2018, which is the largest change in the index of the land and water resource criterion layer, with a range of 0.19. The dynamic evolution index of life function fluctuates down from 2005 to 0.15 in 2007, and continues to rise to 0.20 in 2013, and fluctuates down to 0.15 in 2019. It fluctuates more frequently, but it is the least variable of the indices of the land and water resource guideline layer, which is only 0.05. The dynamic evolution index of ecological function fluctuates and decreases from a maximum of 0.17 in 2005 to 0.04 in 2019, showing an overall fluctuating downward trend. It is the larger index change among the land and water resource guideline layers, with a range of 0.12.

The GDP per unit area (A8) and water consumption per unit of output value (A2), important indicators of production function, changed by 4.29 and 4.46, respectively, during the study period. The indicator of secondary industry water consumption (A4) ranked third in importance, and maximum variation reached 7.85. Traffic density (B3), an important indicator of life function, changed by 4.36 during the study period, also the greatest variation indicator. Forest coverage rate (C1) and SO_2 emission per unit area (C5), as important indicators of ecological functions, varied by 0.26 and 1.31, respectively, during the study period, while sewage treatment rate (C4) ranked third in importance, and maximum variation reached 16.86. It can be seen that under dynamic conditions, the difference between the actual indicators that change a lot and the important indicators is small, and the important indicators determined by the rate of change can be used to reflect the development trend of the soil and water resource system, as well as the planning and management of land and water resources by regulating the important indicators.

4.3. Comparative Analysis of the Evolutionary Characteristics of the "Production–Life–Ecology" Functions of Land and Water Resources under Different Conditions

Under static conditions, the evolution index of the "Production–Life–Ecology" functions of land and water resources reflects the current situation of the development and utilization of land and water resources under a certain time section, so it basically shows a slow growth trend. The large differences between the indicators with large changes in the actual situation and the important indicators assessed in this paper may be due to the fact that the static evolution index of land and water resources is directly influenced by policies and objective conditions, and it is difficult to reflect the differences brought about by the evolution of each indicator and the intensity of action over time, and it is difficult to reflect the differences in the indicators and the intensity of action over time. Under the dynamic conditions, the dynamic evolution index of the "Production–Life–Ecology" functions of land and water resources has obvious fluctuation characteristics, and the overall decline of the dynamic evolution index indicates that the dynamic evolution index, which is determined by the rate of change of indicators, can better reflect the uncertainty in the development and utilization of land and water resources. The overall decreasing trend of the dynamic evolution index also indicates that the ability of the study area to obtain the maximum comprehensive benefits of land and water resources is gradually weakening. Moreover, the difference between the indicators with large data changes and the important indicators during the study period is small, which indicates that managers can use important indicators to make timely adjustments to the planning and management programs of land and water resources.

In determining the important indicators, the differences between the important indicators of livelihood and ecological functions under different conditions are small, and the important indicators with large differences mainly come from the indicators of production functions. And it is clear from the data of each indicator during the study period that the study area has good conditions of agricultural production, abundant water, and forest resources. Therefore, managers should pay attention to the development of non-agricultural industries and promote regional economic development mainly by controlling the rate of development of GDP per unit area (A8), of which GDP per unit area (A8) is an important indicator of the production function. And rational planning of urban land and sewage treatment should be carried out to ensure high-quality living conditions and a livable living environment for residents [40]. While raising awareness of ecological protection, we strengthen ecological security [41], promote the coordinated development of soil and water resource systems, and obtain the best comprehensive benefits of land and water resources in the study area.

5. Conclusions

This paper takes the main grain-producing areas as an example, establishes the indicator system from the "Production–Life–Ecology" functions of land and water resources, uses information entropy to determine the importance of the indicators, conducts a comparative analysis of the actual discrete data and dynamic data of each indicator for the evolution trend, and obtains the following main conclusions:

(1) Under different conditions, the important indices of "Production–Life–Ecology" functions are different. Among production and ecological functions, there are many indicators with a 2% or more difference in indicator importance, while there is only one indicator with great difference in the index importance of life function. The managers should pay attention to the ability of production and economic development ability of land and water resources, as well as the ecological environmental protection ability of land and water resources.

(2) The static evolution indices of the "Production–Life–Ecology" functions of land and water resources basically show a slow growth trend. During the study period, there are differences between the indicators with large data changes and important indicators, so managers can promote the sustainable development of regional land and water resources from four important indicators: the proportion of tertiary industry to GDP, urban land density, forest coverage, and SO_2 emissions per unit area.

(3) The dynamic evolution index of the "Production–Life–Ecology" functions of land and water resources basically shows a fluctuating downward trend. The difference between indicators with large changes and important indicators during the study period is small, so that managers can adjust the evolution mechanism of the land and water resource system in terms of important indicators to produce the best benefit to regional land and water resources.

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