Study on the evaluation system of green development in Tuojiang River Basin based on entropy weight method and grey relation analysis

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Abstract. Based on the definition of green development and the characteristics of the Tuojiang River Basin, nine primary indicators and 17 secondary indicators are selected to establish a green development evaluation system for the Tuojiang River Basin from the four aspects of "economy, society, resource and nature", and the weights of each indicator are determined by entropy method, with Zigong, Luzhou, Deyang, Neijiang and Ziyang as the research objects. The grey correlation method is used to analyze the 2017 statistical data to evaluate the green development of the Tuojiang River Basin and put forward some suggestions.

1. Introduction

The concept of green development is the transformation and upgrading of the concept of sustainable development. From building a two oriented society to taking green development as one of the five development concepts, we can see that we attach great importance to regional green development. All regions also regard green development as an important development concept in the 13th Five Year Plan period and since then [1].

Located in the middle of Sichuan Province, with thousands of medium and large factories, Tuojiang River is a first-class tributary of the Yangtze River. However, due to the industrial development of Tuojiang River Basin and the pressure of population density, Tuojiang River has become the worst forest vegetation among the major rivers in the province [2], and the basin with the most serious water pollution in the province, with only 3.5% of water resources supporting 30% of the total economic output and 26.2% of the population in the province [3], this will affect the ecological security of Sichuan Province and even the Yangtze River Basin, therefore, it has also inspired the research of many domestic scholars [4-6].

Through the above literature, there are some researches on the evaluation system of Tuojiang river basin green development in China, but there are still problems such as the indicator system is not complete, the indicator selection is not fully combined with the characteristics of the basin, and the research method is single. Based on this, this paper establishes the evaluation indicator system to reflect the green development of Tuojiang River Basin and put forward the development suggestions.

2. Research method

2.1. Construction of evaluation indicator system for green development in Tuojiang River Basin
The construction of the indicator system in this paper mainly includes the following four aspects:

1. Establish coupling system and evaluate green development comprehensively: This paper establishes indicators from four aspects of nature, resources, society and economy, which are in line with the direction of green development, forming a coupling system of "economy-society-resource-nature", comprehensive consideration of factors affecting green development of the river basin.

2. Focus on the realization of development under the constraints of environment and resources: reflect the carrying capacity of resources through indicators that characterize resource richness and resource consumption; select the indicators of centralized sewage treatment rate and harmless treatment rate of domestic garbage, which reflects the energy conservation, emission reduction and pollution control required for green development.

3. Select representative indicators based on regional characteristics: since the Tuojiang is an industrial agglomeration with few trees and a large population density, this paper analyzes the indicators that can reflect the regional characteristics, such as the forest coverage rate and the proportion of the tertiary industry in GDP.

4. Indicator selection keeps pace with the times and conforms to future development: in the future, scientific and technological innovation will be used to promote green development, optimize economic structure and achieve low energy consumption and high economy. Therefore, indicators reflecting the relationship between economic structure and economic development and energy consumption is selected, such as the proportion of tertiary industry in GDP, energy consumption per unit GDP, etc.

To sum up, this paper established an evaluation indicator system for green development in the Tuojiang River Basin (Table 1).
Table 1. The evaluation indicator system of the Tuojiang River Basin green development

| Target                  | Primary indicator       | Secondary indicator (unit)          | Serial number | Indicator type     |
|-------------------------|-------------------------|-------------------------------------|---------------|-------------------|
| Economy                 | Economic level          | GDP per capita (10000 yuan)         | X1            | positive correlation |
|                         |                         | Per capita disposable income (10000 yuan) | X2            | positive correlation |
|                         | Industrial structure    | Proportion of tertiary industry in GDP (%) | X3            | positive correlation |
| Society                 | Living standard         | Urban unemployment rate (%)         | X4            | Negative correlation |
|                         |                         | Penetration rate of urban water supply (%) | X5            | positive correlation |
|                         | Educational level       | Proportion of education expenditure in general public budget (%) | X6            | positive correlation |
|                         |                         | Per capita ownership of Public Library(volume) | X7            | positive correlation |
|                         | Medical level           | Number of medical personnel per thousand population(piece) | X8            | positive correlation |
|                         |                         | Number of medical beds per thousand population(piece) | X9            | positive correlation |
|                         | Resource abundance      | Forest coverage (%)                 | X10           | positive correlation |
|                         |                         | Per capita cultivated area (ha)     | X11           | positive correlation |
|                         |                         | Green coverage rate of built-up area (%) | X12           | positive correlation |
|                         | Resource consumption    | Energy consumption per unit GDP (tons of standard coal / 10000 yuan) | X13           | negative correlation |
|                         | environmental quality   | Air quality standard days (%)       | X14           | positive correlation |
|                         |                         | Fertilizer application amount per unit cultivated area (ton / ha) | X15           | negative correlation |
|                         | Pollution control       | Centralized sewage treatment rate (%) | X16           | positive correlation |
|                         |                         | Harmless treatment rate of domestic waste (%) | X17           | positive correlation |

2.2. research method

2.2.1. Entropy weight method
In this paper, the entropy weight method can be used to weight 17 indicators.

\[ x_{ij} = \frac{x_{ij} - \min (x_{ij})}{\max (x_{ij}) - \min (x_{ij})} \]

(1)Standardize the original data, and for the positive indicators, for negative indicators

\[ x'_{ij} = \frac{\max (x_{ij}) - x_{ij}}{\max (x_{ij}) - \min (x_{ij})} \]

(form: \( x_{ij} \) represents the numerical value of indicator \( j \) of the city \( i \), \( i=1,2,3...m \), \( j=1,2,3...n \); \( m \) is the number of inspection cities, \( n \) is the number of indicators; \( \max (x_{ij}) \) and \( \min (x_{ij}) \) represents the maximum and minimum values of indicator \( j \) in all cities).
(2) Calculate the proportion of indicator j of the City i: \( Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \).

(3) Calculate the information entropy of indicator j: \( E_j = -k \sum_{i=1}^{n} (Y_{ij} \times \ln Y_{ij}) \) (e.g., \( Y_{ij} = 0 \) definition \( \lim_{Y_{ij} \to 0} (Y_{ij} \times \ln Y_{ij}) = 0 \)).

(4) Calculate the information entropy redundancy of the indicator j: \( d_j = 1 - E_j \).

(5) Calculate the weight of the indicator j in all indicators: \( \omega_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \).

2.2.2. Grey relation analysis

In this paper, the correlation of green development indicator of five typical cities in the Tuojiang River Basin is calculated to rank the urban green development indexes.

1) Determine the reference sequence \( x_0 \).

2) Calculate the absolute value of the difference between the sample matrix and the standard matrix: \( \Delta_i(k) = |x_i(k) - x_j(k)| \). From \( M = \max_k \max_i |x_i(k) - x_j(k)| \), \( m = \min_i \min_k |x_i(k) - x_j(k)| \) find the maximum difference and the minimum difference M, m.

3) Find the degree of correlation \( \xi_j(k) = \frac{m + \rho M}{\Delta_j(k) + \rho M} \). \( \rho \) is the resolution coefficient, the smaller \( \rho \) is, the stronger the resolution is; the best resolution is achieved when \( \rho \leq 0.5463 \). Generally, \( \rho = 0.5 \).

4) Calculated the grey weighted correlation degree considering the weight difference between each evaluation index: \( \gamma_i = \sum_{k=1}^{n} \omega_j \xi_j(k) \) (where \( k = 1, 2, 3, \ldots, n \), \( \gamma_i \) indicates the weighted correlation between the evaluated sequence \( x_i \) and the reference sequence \( x_0 \).

3. Numerical example

The indicators data of five typical cities were obtain by Sichuan Statistical Yearbook-2018, the 2017 National Economic and Social Development Statistical Bulletin, and the 2017 Environmental Status Bulletin. Follow the steps of 1.2.1 and 1.2.2 to calculate the weights of the indicators (Table 2) and the entropy weight correlation for the green development of the five cities Degrees (Table 3).
Table 2. Evaluation index weight of green development in Tuojiang River Basin

| Target          | Primary indicator          | Secondary indicator (unit) | Serial number | Secondary indicator weight | Primary indicator weight |
|-----------------|----------------------------|----------------------------|---------------|----------------------------|--------------------------|
| Economy         | Economic level             | GDP per capita (10000 yuan) | ω1            | 0.075                      | 0.149                    |
|                 | Per capita disposable income (10000 yuan) | ω2 | 0.074 |
|                 | Industrial structure       | Proportion of tertiary industry in GDP (%) | ω3 | 0.093                      | 0.093                    |
| Living standard | Urban unemployment rate (%) | ω4 | 0.102 |
| Society         | Penetration rate of urban water supply (%) | ω5 | 0.032 |
| Educational level | Proportion of education expenditure in general public budget (%) | ω6 | 0.042 |
| Medical level   | Per capita ownership of Public Library (volume) | ω7 | 0.129 |
| Resource        | Forest coverage (%)        | ω10 | 0.043 |
| Resource        | Per capita cultivated area (ha) | ω11 | 0.118 |
| consumption     | Green coverage rate of built-up area (%) | ω12 | 0.040 |
| Environmental quality | Energy consumption per unit GDP (tons of standard coal / 10000 yuan) | ω13 | 0.037 |
| Pollution control | Air quality standard days (%) | ω14 | 0.035 |
|                 | Fertilizer application amount per unit cultivated area (ton / ha) | ω15 | 0.038 |
|                 | Centralized sewage treatment rate (%) | ω16 | 0.035 |
|                 | Harmless treatment rate of domestic waste (%) | ω17 | 0.032 |

Table 3. Entropy weight correlation degree of green development of the five typical cities

| Object              | Zigong | Luzhou | Deyang | Neijiang | Ziyang |
|---------------------|--------|--------|--------|----------|--------|
| City grey correlation | 0.725  | 0.834  | 0.803  | 0.659    | 0.797  |

4. Discuss

According to the above data analysis, it can be obtained that the green development index of the Tuojiang River Basin is generally not high and the level of urban green development is uneven. The green development indexes of Luzhou and Deyang are higher than 8.0, while Neijiang is only about 6.5. Based on this, the following suggestions are made:

(1) Popularize the concept of green development and cultivate high-quality talents. Campuses, companies, governments, etc. need to work together to disseminate green knowledge to every citizen, and at the same time guide people to continuously learn about the concept and connotation of green so as to promote the development of green economy.

(2) Accelerate the transformation of industrial structure and develop green industry. As an industrial cluster in Sichuan Province, Tuojiang needs to transform and upgrade the traditional industrial model with the help of new ideas, new technologies and new equipment to reduce the negative impact of economic and social development on resources, energy consumption and ecological environment.

(3) Optimize resource utilization and develop new types of energy. Pay more attention to the rational development and utilization of resources, the promotion of resource recycling, and the recycling of waste; in addition, we should increase the proportion of clean energy in the energy consumption, adjust the energy structure, protect the natural resources of the Tuojiang River Basin.
(4) Increase support for green causes and improve green development policies. Specifically, it can increase support for green industries, strictly control heavily polluting enterprises, encourage and promote green technologies, and use strong laws to ensure green development.

5. Conclusions
Through the establishment of the evaluation indicator system of green development in Tuojiang River Basin, this paper evaluates five typical cities in Tuojiang River Basin, and finds that the green development index of Tuojiang River Basin is generally not high. The ranking of green development level is Luzhou, Deyang, Ziyang, Zigong and Neijiang, with scores of 0.834, 0.803, 0.797, 0.725 and 0.659. For Neijiang, the main reason for its lowest level of green development is that it has slow economic and environmental development, per capita GDP and disposable income of residents are the lowest in the five cities, while resource consumption is the highest, and environmental governance is relatively behind, but under the condition of good economic development, Deyang also maintains a good environmental quality. Based on this, this article also puts forward related suggestions. Therefore, the Tuojiang River Basin needs to learn from relevant experiences, so as to ensure the coordinated development of the basin's ecology, economy, and society.

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