Evaluation of River Health from the View Angle of ‘the New Vision for Development’

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Abstract. Along with the rapid development of China’s economy, environmental problems such as water pollution have been prominent. Hence, ‘the New Vision for Development’ was proposed. ‘The New Vision for Development’ complies with the trend of development in today’s world and puts forward new requirements for the development of China nowadays. Meanwhile, the introduction of river health assessment has promoted the development of river management in China. In order to evaluate river health more scientifically and make river management more efficient, this paper defined the connotation of river health evaluation from the view angle of ‘the New Vision for Development’ and adopted the Pressure-State-Response framework concept to establish an evaluation index system. Then the fuzzy evaluation model was constructed through grey clustering and grey correlation analysis. Finally, the applicability of the method was proved through a case study. The study provides an effective method for river health assessment.

1. Introduction

The report of the 19th National Congress of the Communist Party of China (CPC) pointed out that “Adopting a new vision for development. Development is the underpinning and the key for solving all our country’s problems; our development must be sound development. We must pursue with firmness to the vision of innovative, coordinated, green, and open development, which is for everyone.” The five development concepts were proposed by Xi Jin-ping at the Fifth Plenary Session of the 18th CPC Central Committee. Innovation is the core of the national development, coordination is essential for the healthy development, green is the inherent requirement of sustainable development, opening up complies with the trend that China’s development is deeply integrated into the world and sharing is in line with people’s aspiration for a better life. ‘The New Vision for Development’ is a profound reform that concerns the overall development of China and new requirements for the development of contemporary China.

The extensive development mode in the past has led to unbalanced development, tighter resource constraints and prominent environmental problems in China. Water environment problem is an important part of it. Water is a necessary resource for all living things and plays an important role in life evolution. Rivers are the main source of biological water resources. It has created a good environment for human survival in the course of history and is of great significance to human beings.
Due to water pollution and ecosystem degradation in different degrees around the world, people began to take actions to protect rivers, and the concept of river health came into being. The concept of river health was first put forward by the United States, and then different scholars analysed it. Some scholars believe that river health means the balance, integrity and adaptability of river ecosystem[1], while others believe that healthy rivers should also meet the needs of human society[2-6]. With the continuous development of the concept of river health and the in-depth study of many scholars, river health evaluation has become an important means to diagnose the condition of river water and guide river management[7-10].

At present, there are abundant research results on river health evaluation, and the evaluation methods mainly include indicator species method and comprehensive evaluation index method. The former focuses on the evaluation of water quality and can’t reflect the comprehensive level of rivers. The latter is more objective and widely used. The connotation and evaluation framework of river health have not been unified. Most of the foreign studies focus on the evaluation of ecosystem structure. Mondy(2012) studied the response of macrobenthos to anthropogenic ecological disturbance[11]. Virtanen(2016) used diatoms as an indicator to measure the chemical quality of water[12]. Most Chinese scholars have brought the social service function of rivers into the evaluation content and evaluated different rivers[13-19]. In terms of the evaluation model, most scholars use two evaluation methods comprehensively to make the evaluation results more accurate. Liu, Q.(2014) combined extension matter-element method with fuzzy evaluation[20]. Zhao, Y.W.(2005)[21], Qin, P.(2011)[22], Shan, C.J.(2012)[23], Deng, X.J.(2014)[24] et al. evaluated river health by fuzzy hierarchy method. In terms of the determination of index weight, the accuracy of single method is not enough. Analytic hierarchy process and entropy weight method are most widely used. The shortage of entropy weight method lies in the need of multi-group data analysis, which makes it lack of universal applicability. At present, due to the lack of research on the connotation of river health evaluation, the evaluation work is not comprehensive enough.

Based on this, this paper attempted to analyse the connotation of river health evaluation from the view angle of ‘the New Vision for Development’. Then the evaluation index system of river health was established based on PSR model. Grey clustering and grey relational degree were used to calculate the objective weight of indexes, and then combined with the analytic hierarchy process to give the final weight. Finally, fuzzy evaluation was given. This method improves the accuracy of evaluation to a certain extent. It can provide support for guiding river management and improving river development.

2. The connotation of river health evaluation from the view angle of ‘the New Vision for Development’

At present, the connotation of river at home and abroad is mainly understood from the integrity of river ecosystem and the value of social services. Because there is no in-depth analysis of the connotation of river health evaluation, the evaluation system is not complete. The purpose of river health evaluation is to guide river management, and the reports of the 19th National Congress of the Communist Party of China pointed out that “Development is the basis and key to solving all the problems in our country.” Therefore, this paper defines the connotation of river health evaluation from the perspective of new development concept. Based on the requirement of comprehensive development and sustainable development, the connotation of river health evaluation is enriched and improved in two dimensions of space scale and time scale.

2.1. Determine the evaluation object

‘The New Vision for Development’ includes the concepts of innovation development, balanced development, green development, open development and development for all, which are different manifestations of sustainable development. The core idea of the concept of open development is to build a community of shared interests. The development of anything is not isolated. The health of rivers is inseparable from the environment in which they are located, especially the impact of human...
activities on rivers. Human beings have greater subjective initiative in river health, and most of the influencing factors may ultimately point to human factors. Therefore, it is obviously one-sided to limit the evaluation object to the river itself. In terms of space, the evaluation object of river health should be extended to the ecological environment around the river and the human society. The concept of green development focuses on solving the problem of harmony between man and nature and handling the relationship between development and environment. For river health, this is to solve the root problem, which is the key to river health. Therefore, it is necessary to bring human society into the category of evaluation objects. Jaiswal (2019) studied the effects of human activities on river health[25]. In addition, everyone is a stakeholder in river health. The concept of development for all adheres to the principle that development is for the people, development depends on the people and the fruits of development are shared by the people. The evaluation of human society should not only focus on river managers, but also consider the public.

2.2. Define the evaluation time
The current evaluation of river health is based on the evaluation at a certain point in time. This is static evaluation, lacking objectivity and scientific. ‘The New Vision for Development’ requires that development be scientific and sustainable. The previous extensive development model makes our country develop imbalanced, ignored environmental problem. The concept of coordinated development emphasizes the balance, harmony and sustainability. This will fundamentally change the extensive development model of the past and guarantee the long-term health of rivers. The concept of innovative development requires the continuous promotion of comprehensive innovation with scientific and technological innovation as the core, including theoretical innovation, institutional innovation and cultural innovation. Sustainable development is a dynamic and long-term process, not a temporary state. Under ‘the New Vision for Development’, the river health evaluation should also be dynamic. For example, the identification of potential risks of river health can predict the future trend of river health. Zhao, C.S. et al. (2019) studied the methods to predict river health under different climate changes[26], providing method support for the scientific prediction of river health.

2.3. Strengthen the role of evaluation
The evaluation of the integrity of the river ecosystem and the function of social services can only reflect the appearance of the problem. Extending the connotation of evaluation in spatial scale can make the root cause of the problem appear and improve the efficiency of river management. The extension of evaluation connotation on the time scale can play an early warning role to prevent potential health risks of rivers, avoid unnecessary damages and ensure the sustainability of healthy development of rivers. In general, the richness of evaluation connotation in space and time makes the evaluation system more complete and more dynamic.

To sum up, river health evaluation is a dynamic evaluation of the river itself, the surrounding ecological environment and the interest community of human society.

3. Establishment of river health evaluation index system
Pressure-State-Response (PSR), the concept has been widely adopted in environmental evaluation researches. It holds that human social and economic activities affect the quality of the environment and natural resources, putting pressure on the environment and natural resources. In turn, society has responded with a series of measures to alleviate the pressure brought by human activities on the environment and natural resources. A number of scholars have applied it to river health evaluation. However, due to fewer researches bringing human impact on river health into the evaluation system, human response to river health is not reflected in the response criterion layer, but river service function to human is classified as the response criterion layer. This paper argues that it is inconsistent with the concept of PSR framework.
Based on the connotation of river health evaluation under ‘the New Vision for Development’, this paper attempts to construct a river health evaluation index system by applying PSR model, as shown in Table 1.

Table 1. The river health evaluation index system.

| Target layer | Criteria layer | Primary index | Secondary index | Description |
|--------------|----------------|---------------|-----------------|-------------|
|              | Ecological environment | The rate of soil erosion \( C_{11} \) | It is the proportion of the area where soil erosion occurs to the total area of the basin. |
|              | Human factors \( C_2 \) | The degree of equilibrium between precipitation and evaporation \( C_{12} \) | It is the ratio of annual average evaporation to annual average precipitation. |
|              | The situation of river ecological environment \( C_3 \) | Human activity intensity \( C_{21} \) | It is represented by the population density within the basin. |
|              | | The rate of water resources development \( C_{22} \) | It is the ratio of water resources development to total water resources. |
|              | State | The rate of basin land development \( C_{23} \) | It is the ratio of land development area to total land area of the basin. |
|              | | Biodiversity \( C_{31} \) | Biological integrity index (IBI) is used for evaluation. |
|              | | Vegetation coverage \( C_{32} \) | It is represented by NDVI value of natural vegetation in the basin. |
|              | | Cleaning situation \( C_{33} \) | We use marking system for evaluation. |
|              | | Water quality \( C_{41} \) | Average water pollution index (WQI) is used to evaluate the water quality. |
|              | | River connectivity \( C_{42} \) | It is represented by the reservoir capacity of Regulation of river course obstacle runoff. |
|              | | The rate of flood guarantee \( C_{43} \) | It is represented by the probability of the number of years in which the expected water supply can be fully satisfied in a multi-year supply. |
|              | | The rate of Irrigation maintenance \( C_{44} \) | It is the ratio of the actual irrigated area to the effective irrigated area. |
|              | | The capacity of flood storage \( C_{45} \) | It is represented by the proportion of river length with qualified flood control measures to the total river length. |
|              | | The degree of public participation \( C_{51} \) | It is represented by the proportion of number of projects which Public participated in river management and decisions to the total number of projects. |
|              | The situation of human society \( C_5 \) | The sense of river health \( C_{52} \) | It can be judged by scientific research, propaganda and education of river protection. |
4. Evaluation model

4.1. Calculate the grey membership degree

Experts are invited to evaluate target layer and primary indexes. There are A, B, C and D four evaluation grey classes, using ‘in accord with’, ‘in accord with basically’, ‘between in accord with and not in accord with’, ‘not in accord with basically’ and ‘not in accord with’ five qualitative expressions to describe the relationship between the object and evaluation grey classes. At the same time, reference matrix \([1, 0.75, 0.5, 0.25, 0]\) is set to be correspond to five qualitative expressions. Experts can do adjustments on the basis of the reference matrix when they do evaluations. The membership degree of experts’ evaluation of object ‘i’ to grey class ‘m’ is \(f_i^m\).

Secondary indexes obtain index values according to statistics and surveys. Each index is divided into A, B, C and D four grey classes, letting \(x_{ij}\) be the value of object ‘i’ to the index ‘j’, with the value range \([a_{ij}^a, a_{ij}^b]\). Then, calculate the grey membership degree by using triangle whiten function. Set 

\[
\lambda_{ij}^m = \frac{1}{2} (a_{ij}^a + a_{ij}^{a+1})
\]

and let the whitenization weight function value which belongs to the number ‘m’ grey class be 1. Connect the point \((\lambda_{ij}^m, 1)\), the starting point of the number ‘m-1’ grey class \((a_{ij}^{a-1}, 0)\) and the ending point of the number ‘m+1’ grey class \((a_{ij}^{a+2}, 0)\), and we can get the triangle whiten function of index ‘j’ to grey class ‘m’:

\[
f_{ij}^m \left( x_{ij} \right) = \begin{cases} 0, & x_{ij} \notin [a_{ij}^{a-1}, a_{ij}^{a+2}] \\ \left( x_{ij} - a_{ij}^{a-1} \right) \left( \lambda_{ij}^m - a_{ij}^{a-1} \right)^{-1}, & x_{ij} \in [a_{ij}^{a-1}, \lambda_{ij}^m] \\ \left( a_{ij}^{a+2} - x_{ij} \right) \left( a_{ij}^{a+2} - \lambda_{ij}^m \right)^{-1}, & x_{ij} \in [\lambda_{ij}^m, a_{ij}^{a+2}] \end{cases}
\]
For \( f_{ij}^1(x_{ij}) \) and \( f_{ij}^4(x_{ij}) \), we value index ‘j’ the continuation values both of which locate in the left and the right of the number field \( a_{ij}^0 \) and \( a_{ij}^6 \).

### 4.2. Determine the weight

#### 4.2.1. Objective empowerment

Based on grey correlation analysis, calculate the correlation degree between secondary indexes and primary indexes, primary indexes and target layer:

\[
\rho = \frac{1}{4} \sum_{m=1}^{4} \min_{j} \min_{m} |f_{ij}^m - f_{mj}^m| + \rho \max_{j} \max_{m} |f_{ij}^m - f_{mj}^m| \\
(2)
\]

In the formula, \( f_{ij}^m \) represents the membership degree of object ‘i’ to grey class ‘m’, \( f_{ij}^m \) represents the membership degree of index ‘j’ of object ‘i’ to grey class ‘m’, while \( \min_{j} \min_{m} |f_{ij}^m - f_{mj}^m| \) respects the minimum absolute difference value and \( \max_{j} \max_{m} |f_{ij}^m - f_{mj}^m| \) respects maximum absolute difference between \( f_{ij}^m \) and \( f_{mj}^m \). \( \rho \in [0, 1] \). Generally taking \( \rho = 0.5 \).

As a measure of the correlation measurement between each factor in the system, the greater the correlation degree is, the closer the relationship between sub-factor and the main factor is. Therefore, correlation degree and weight are interlinked in the basic sense, and it is feasible to replace the weight by necessary treatment of correlation degree. The correlation degree can be converted to weight by the following formula:

\[
w_{ji} = \rho \left( \sum_{j=1}^{k} r_{ij} \right)^{-1} \\
(3)
\]

‘k’ is the amount of indicators.

#### 4.2.2. Subjective empowerment

We use the analytic hierarchy process (AHP) and invite experts to compare the importance of indexes and construct judgment matrix. After consistency test and correction, we calculate the product of each row of the judgment matrix elements \( M_j = \prod_{i=1}^{n} a_{ji} \ (j=1, 2, \ldots, n) \), finally determine the index weight is:

\[
w_{ij} = (M_j)^{1/n} \left( \sum_{j=1}^{n} (M_j)^{1/n} \right)^{-1} \\
(4)
\]

#### 4.2.3. Combined empowerment

In order to comprehensively consider the influence of subjective and objective factors in index weighting, this paper adopts the following formula to process the weights obtained by the two methods:

\[
w_j = (w_{ji} + w_{ij}) \left[ \sum_{j=1}^{n} (w_{ji} + w_{ij}) \right]^{-1} \\
(5)
\]
4.3. Fuzzy evaluation

According to the obtained weights, the grey clustering coefficient of the primary indexes and the target layer is calculated:

\[
\sigma_i^m = \left[ w_i, w_{i2}, \ldots, w_n \right] \odot \begin{bmatrix}
    f_{i1}^1 & f_{i1}^2 & f_{i1}^3 & f_{i1}^4 \\
    f_{i2}^1 & f_{i2}^2 & f_{i2}^3 & f_{i2}^4 \\
    \vdots & \vdots & \vdots & \vdots \\
    f_{ij}^1 & f_{ij}^2 & f_{ij}^3 & f_{ij}^4
\end{bmatrix}
\]

(6)

Then the clustering coefficient matrix is \([\sigma_i^1, \sigma_i^2, \sigma_i^3, \sigma_i^4]\), where \(\odot\) represents the fuzzy operator. According to the principle of maximum clustering coefficient, the grey class of the object is determined. By \(\max \{\sigma_i^m\} = \sigma_i^m\), it can be judged that object 'i' belong to the grey class 'm'.

5. Case analysis

To evaluate the health of river A, relevant statistics and surveys were conducted to obtain secondary index values. In order to make the evaluation more accurate, 5 experts were invited to evaluate the primary indexes and target level. They were also asked to classify the evaluation of grey classes of secondary indexes and compare the importance of indexes according to the analytic hierarchy process.

Three of the experts are experts in the field of rivers and two are experts in the field of ecological environment. Take \(C_2\) and \(c_{21}, c_{23}\) as examples, and the relevant data is shown in Table 2.

| Index | Index value | Grey partition |
|-------|-------------|----------------|
| \(C_2\) | [0.15, 0.70, 0.10, 0.05] (Assume that experts equal weight) | Unit: people·km\(^{-2}\) |
| \(c_{21}\) | 185 people·km\(^{-2}\) | A: \(c_{21} < 100\) ; B: 100 \(\leq c_{21} < 400\) \[\text{C: } 400 \leq c_{21} < 700\) ; D: \(c_{21} \geq 700\) |
| \(c_{22}\) | 20% | A: \(c_{22} < 10\) % ; B: 10% \(\leq c_{22} < 35\) % \[\text{C: } 35\% \leq c_{22} < 60\) % ; D: \(c_{22} \geq 60\) % |
| \(c_{23}\) | 15% | A: \(c_{23} < 10\) % ; B: 10% \(\leq c_{23} < 35\) % \[\text{C: } 35\% \leq c_{23} < 60\) % ; D: \(c_{23} \geq 60\) % |

5.1. Analysis process

STEP1: Formula (1) is used to calculate the membership degree of grey class. The index \(c_{21}, c_{23}\) grey membership degree is shown in Table 3.

| Index | Grey membership degree |
|-------|-----------------------|
| \(c_{21}\) | [0.6286, 0.7200, 0.1778, 0] |
| \(c_{22}\) | [0.5000, 0.8889, 0.2667, 0] |
| \(c_{23}\) | [0.6670, 0.6667, 0.1333, 0] |

STEP2: The correlation degree between secondary indexes and primary indexes is calculated according to formula (2), and the weight is calculated according to formula (3). Then the analytic
hierarchy process is applied to subjective weighting, and combined weighting is carried out according to formula (5). The correlation degree and weight of $c_{2_1}$, $c_{2_3}$ and $C$ are shown in Table 4.

| Index | Correlation degree | Objective weight | Subjective weight | The combination weights |
|-------|--------------------|------------------|-------------------|-------------------------|
| $c_{2_1}$ | 0.7771             | 0.3486           | 0.1400             | 0.2443                   |
| $c_{2_2}$ | 0.6594             | 0.2958           | 0.5736             | 0.4347                   |
| $c_{2_3}$ | 0.7927             | 0.3556           | 0.2864             | 0.3210                   |

STEP3: Calculate the grey clustering coefficient of primary indexes and the target layer according to formula (6). In this paper, product- sum fuzzy operator is used for calculation. Take $C$ as an example:

$$\sigma_i^* = \left[ 0.2443, 0.4347, 0.3210 \right] \odot \left[ 0.6286, 0.7200, 0.1778, 0 \right] = [0.5849, 0.7763, 0.2022, 0]$$

According to the maximum principle of clustering coefficient, the evaluation levels of $c_{2_1}$, $c_{2_2}$ and $c_{2_3}$ are B, B and A respectively, and the evaluation levels of $C$ are B. Similarly, the weights and evaluation levels of other indexes can be obtained, as shown in Table 5.

| Target layer | Level | Primary index | Weight | Level | Secondary index | Weight | Level |
|--------------|-------|---------------|--------|-------|-----------------|--------|-------|
| $C_1$ | 0.0845 | C | $c_{1_1}$ | 0.5867 | C |
| | | | $c_{1_2}$ | 0.4133 | B |
| | | | $c_{2_1}$ | 0.2443 | B |
| $C_2$ | 0.1443 | B | $c_{2_2}$ | 0.4347 | B |
| | | | $c_{2_3}$ | 0.3210 | A |
| | | | $c_{3_1}$ | 0.4679 | C |
| $C_3$ | 0.1671 | C | $c_{3_2}$ | 0.2772 | C |
| Rivers health status | C | | | |
| $C_4$ | 0.1603 | B | $c_{4_1}$ | 0.2748 | C |
| | | | $c_{4_2}$ | 0.1338 | B |
| | | | $c_{4_3}$ | 0.2397 | B |
| | | | $c_{4_4}$ | 0.1882 | B |
| | | | $c_{4_5}$ | 0.1635 | C |
| $C_5$ | 0.0854 | C | $c_{5_1}$ | 0.4196 | C |
| | | | $c_{5_2}$ | 0.5804 | C |
| $C_6$ | 0.1387 | C | $c_{6_1}$ | 0.5298 | B |
| | | | $c_{6_2}$ | 0.4702 | C |
5.2. Analysis results
The results show that the overall health evaluation of river A is level C. Among them, the river management innovation and hidden danger prevention are obviously deficient, and the evaluation levels are D. The specific analysis is as follows:

5.2.1. Insufficient innovation ability
Innovation is a key to solving the problems of driving force for development and should be at the core of development. It can be seen from the results that evaluation levels of the river ecological environment status index and water quality index are both C. The lack of innovation is an important reason for the ineffective solution of river ecological environment and water quality problems. ‘The New Vision for Development’ calls for sustainable development, and if the fundamental problem of the driving force of river A’s development is not solved, it will be difficult to guarantee the long-term healthy development of the river.

5.2.2. Insufficient awareness of hidden dangers
The results showed that the indexes of health risk identification and health risk control rate of river A are both level D. Therefore, it can be seen that the prevention of hidden dangers in river A is still not in place. Risks of river health are not sufficiently identified and identified risks are not effectively controlled. Only a comprehensive and scientific identification of risks can lead to adequate preparations for potential problems. At the same time, smaller problems, if not handled properly, may develop further and lead to adverse consequences. Therefore, in terms of time scale, the management of river A should not only stay in the present, but also focus on the future.

5.2.3. Public awareness of river protection needs to be strengthened
The indexes of public participation and river health awareness in river A management are both level C. The civic awareness is the key to the healthy development of rivers and the important premise for the smooth progress of river management. The management of river A should strengthen the publicity and education of river protection, and let more people participate in river management. The development idea that development is for the people, development depends on the people, and the fruits of development are shared by the people must be carried through.

6. Conclusion
‘The New Vision for Development’ is the guidance of managing the overall situation, fundamental and long-term development. River health needs to control the impacts from the overall situation, fundamentally solve the problems, and consider development in the long run. ‘The New Vision for Development’ is the requirement of times development and a guide to the health of rivers that can go far.

(1) Based on ‘the New Vision for Development’, this paper defines the connotation of river health evaluation from five aspects: innovation, coordination, green, openness and sharing. The river health evaluation is improved and developed in two dimensions of space and time. Using the PSR model constructs the evaluation index system of river health. Grey clustering and grey correlation analysis are combined to objectively weight indexes. And then subjective weighting based on analytic hierarchy process is combined to improve the accuracy of weight determination. Finally, fuzzy evaluation is given by grey membership degree.
This paper proves the feasibility of the method through case analysis. The analysis shows that the evaluation method constructed in this paper can reflect the existing problems in river management better, and can also trace the internal reasons behind the problems. At the same time, it can warn the managers to prevent the river health hazards, so as to ensure the sustainable development of the river. The method can make a comprehensive and profound evaluation on river health.

In this paper, the connotation of river health evaluation is improved to a certain extent, and further analysis is needed to give a more scientific definition. The evaluation method also needs further innovation to improve the accuracy of evaluation.

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