Study on Assessment Index System of Water Resources

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Abstract. Taking strategy of sustainable development as a guide, the paper briefly explains the connotation of sustainable utilization of water resources, and establishes assessment index system, including water resources, social development, economic growth and ecological environment, and determines assessment index criteria. The AHP is used to determine weight and the grey correlation is used to build assessment model. The assessment index system of water resources is studied in combination with socio-economic development and ecological environmental protection criteria.

Keywords: water resources; sustainable utilization; index system; assessment, analytic hierarchy process (AHP).

1. Introduction
Sustainable development is a development strategy for countries around the world, sustainable utilization of water resources is a resource utilization model under the framework of sustainable development, it can support coordinated growth of population, resources, environment, economy and meet human water needs under the premise of maintaining water sustainability and ecosystem integrity, sustainable development is a reasonable way of integrating development, usage and protection of water resources, which is characterized by complexity, extensiveness and dynamics. According to the development status of the aquatic environment in specific area, a set of assessment index system which can reflect or measure water resources can be established, and correct methods are used to assess sustainable utilization of water resources; it has great significance for sustainable development of water resources, socio-economic, as well as ecological environment.

2. Construction Principles of Assessment Index System of Water Resources
The water resources utilization has typical multi-level and multi-index characteristics. The influence of social, economic, ecological environment and features of water resources should be considered to ensure sustainable utilization of water resources. The establishment of assessment index system of water resources should take into account the features of river basin and regional water resources, consider socioeconomic development imbalance, the water resources development and utilization level, and differences in local science and technology levels, and fully consider the scientific, practical, and concise selection principles.

The establishment of water resources assessment index system should follow the following principles. The first is the scientific principle, the name of the index should be standardized, the meaning should be clear, the measurement method should be standard, and the calculation method should be standardized. The index system should fully reflect the main characteristics and development condition of water
resources utilization in river basin. The second is the operational principle; the acquisition of indicators is feasible, the data can be obtained from the existing statistical reports, such as yearbook data, sampling or typical surveys. The third is the representation principle; representative, independent, and typical index should be selected to avoid similar, overlapping, and repetitive indicators. The fourth is the hierarchy principle; the selection of the index system should be hierarchical, and has clear thinking and clear objectives, so create conditions for further factor analysis. The fifth is the dynamics principle; the indicator system must reflect the development status of the system and reflect the development process of the system, so that the assessment model has flexibility, the assessment index system water resources as shown in Fig.1.

3. Basic Principles and Methods

3.1. Basic principles of AHP

AHP is a multi-criteria decision method, it can divide the target into several levels, and the experts judge the importance of the indexes at each layer, then determine the weight of the lower indicators to the upper indicators through calculation, and finally calculate the weight value of the most basic index to the total target.

3.1.1. Construction of judgment matrix. In the hierarchical structure, the related elements among the levels are compared, and the ranks are evaluated in accordance with their importance to form a matrix form, namely a judgment matrix. It is generally determined with the scaling method.
3.1.2. **Matrix consistency examination.** The consistency index is \( CI = \frac{\lambda_{\text{max}} - n}{n-1} \), random consistency index is \( RI \), consistency ratio index is \( CR = \frac{CI}{RI} \).

3.1.3. **Calculate the weight vector.** For the weight calculation of each index, the commonly used calculation methods are geometric average method (root finding method) and sum product method. The geometric average method is used, and the calculation formula is

\[
w_i = \frac{(\prod_{j=1}^{n} a_{ij})^{1/n}}{\sum_{i=1}^{m} (\prod_{j=1}^{n} a_{ij})^{1/n}}
\]

In the above formula, \( i, j = 1, 2, \cdots n \).

3.2. **Grey relation analysis**

The basic idea of gray correlation method is based on data sequence of factors, and geometric correspondence among the factors is studied mathematically, namely the closer the geometric shapes of curves are, the greater the correlation among them. Calculation steps: determine the number of samples in the assessment index set, and determine the index series level of the assessment index and the weight of the index; carry out dimensionless processing on the index data and convert them into comparable data sequences; calculate the correlation coefficient of each index in the sample series for different standard series; calculate the correlation between the sample sequence and different standard sequences, and get the comprehensive assessment results according to the principle of maximum correlation.

3.3. **Index assessment criteria**

The determination of assessment standards mainly refers to 5 points: if there are national standards or international standards, the prescribed standard values are used; the standard value is determined with reference to the national development plan values on certain indicators or the actual values of indicators in developed countries and regions; the standard value is determined by referring to the existing literature; based on the theoretical analysis and the characteristic value of the current situation in typical regions;

4. **Case Studies**

Taking the Hunhe river basin as an example, the water resources are evaluated. The Hunhe River originates from Changbai Mountains, from northeast to southwest; it flows through Fushun, Shenyang, Liaoyang, Anshan and other cities, its total length is 415.40 km and basin area is 11,481 km². It flows south to the vicinity of Yingkou City and enters the Liaodong Bay into the Bohai Sea. According to the requirements of AHP, the hierarchical diagram of sustainable use assessment of water resources in Hunhe River basin is established, as shown in Fig.2, and weight of every index is fixed in accordance with the AHP calculation steps: 0.089 (C1), 0.218 (C2), 0.049 (C3), 0.049 (C4), 0.055 (C5), 0.022 (C6), 0.135 (C7), 0.058 (C8), 0.175 (C9), 0.112 (C10), 0.037 (C11).
By referring to the above index assessment criteria, the principle of multivariate statistical analysis is used to divide the assessment index levels, finally, 11 assessment indexes are divided into 5 levels: very good, good, ordinary, poor, very poor, and every level gives one quantitative range as the identification criteria, the assessment criteria as shown in Table 1.

**Table 1. Assessment criteria of sustainable utilization for water resources**

| assessment indexes                                      | index level division |
|---------------------------------------------------------|----------------------|
| water production modulus(10000m³/km²)                  | ≥40                  |
| water resources per capita(m³/person)                  | ≥4000                |
| surface water development and utilization level(%)     | ≤40                  |
| groundwater development and utilization level(%)        | ≤50                  |
| population density (person/km²)                        | ≤200                 |
| urbanization rate(%)                                    | ≥70                  |
| water consumption per capita(m³/person)                | ≥1000                |
| GDP per capita(yuan/person)                            | ≥50000               |
| GDP per cubic meter of water(yuan/m³)                  | ≥150                 |
| ecological water utilization rate(%)                   | ≥5                   |
| COD concentration in water(mg/L)                       | ≤15                  |

| index level division | very good | good | ordinary | poor | very poor |
|----------------------|-----------|------|----------|------|-----------|
| ≥40                  | 30-40     | 20-30| 10-20    | ≤10  |
| ≥4000                | 2000-4000 | 1000-2000 | 500-1000 | ≤500 |
| ≤40                  | 40-50     | 50-60| 60-70    | ≥70  |
| ≤50                  | 50-60     | 60-70| 70-80    | ≥80  |
| ≤200                 | 200-350   | 350-500 | 500-750  | ≥750 |
| ≥70                  | 60-70     | 50-60| 40-50    | ≤40  |
| ≥1000                | 750-1000  | 550-750 | 300-550  | ≤300 |
| ≥50000               | 40000-50000 | 30000-40000 | 20000-30000 | ≤20000 |
| ≥150                 | 120-150   | 90-120| 50-90    | ≤50  |
| ≥5                   | 4-5       | 3-4  | 2-3      | ≤2   |
| ≤15                  | 15-20     | 20-30| 30-40    | ≥40  |
According to the basic principle and calculation steps of the gray correlation method, the correlation discrete values of every assessment index and 5 levels are determined, and the correlation is determined by the obtained correlation discrete values and index weights, it is shown in Table 2.

| level   | C1    | C2    | C3    | C4    | C5    | C6    | C7    | C8    | C9    | C10   | C11    |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| very good | 0.3210 | 0.0000 | 0.4125 | 0.0000 | 0.0047 | 1.0000 | 0.0201 | 0.3500 | 0.4140 | 1.0000 | 0.0000 |
| good    | 0.5823 | 0.1429 | 0.7154 | 0.1429 | 0.1490 | 0.6000 | 0.1691 | 0.6241 | 0.7175 | 0.6000 | 0.1429 |
| ordinary | 0.9725 | 0.3333 | 0.8449 | 0.3333 | 0.3417 | 0.3333 | 0.3693 | 0.9636 | 0.8424 | 0.3333 | 0.5333 |
| poor    | 0.6181 | 0.6000 | 0.4991 | 0.6000 | 0.6120 | 0.1429 | 0.6520 | 0.5766 | 0.4975 | 0.1429 | 0.6000 |
| very poor | 0.3459 | 1.0000 | 0.2625 | 1.0000 | 0.9816 | 0.0000 | 0.9243 | 0.3170 | 0.2614 | 1.0000 | 0.5905 |

On the basis of maximum correlation principle, sustainable development of water resources in Hunhe River basin is at very poor level, it shows that the sustainable utilization condition of water resources in the Hunhe River basin is not good; this assessment result tallies with situation of water resources system in local water transfer project.

5. Conclusion
The assessment index system of water resources needs to be studied by integrating social development, economic growth and ecological environmental protection. The AHP is used to determine index weight, and grey relational model is used to assess sustainable utilization condition of water resources, so assessment results fully and truly reflect the utilization condition of water resources.

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