Study on water resources management in Henan Province based on principal component analysis

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Abstract. This paper selects 11 indicators from three aspects of water resources environment, economy and society to construct the water resources management evaluation system, and uses the principal component analysis method for analysis. Through the comprehensive evaluation of the water resources management level of Henan province in the past three years, the water resources management level of Henan province is compared to promote its management level and improve the efficiency of water resources utilization. The results show that: 1. The water resource utilization level in Henan province is stable and improving. 2. Cities with best water resource management include Zhengzhou, Luoyang, Xinxing and Nanyang, while cities with good water resource management include Kaifeng, Pingdingshan, Anyang, Jiaozuo and Xinyang. 3. The water resources management level and the economic development level correlation degree is big, and the social development level correlation degree is small.

1. Introduction
With the rapid development of economy, the use and protection of water resources are becoming more and more important. The 19th National Congress of the Communist Party of China pointed out that building ecological civilization is a millennium plan for the sustainable development of the Chinese nation. We must establish and practice the idea that green water and green mountains are mountains of gold and silver. To coordinate the systematic management of mountains, rivers, forests, fields, lakes and grass, and implement the most stringent ecological and environmental protection system. We need to develop a green development model and a way of life, and firmly follow the path of civilized development featuring increased production, affluent living and sound ecology. Construction of beautiful China, for the people to create a good production and living environment, and contribute to the global ecological security [1]. The management of water resources carrying capacity becomes the important weight of regional sustainable development [2,3]. Water resource has become an important factor restricting the sustainable development of China's social economy [4]. As the basic elements of sustainable development, water resource is one of the focuses of the security policy of water resources bearing capacity management problems [5-8]. In addition, water resource management is also the focus of economic method research [9-11]. The main research focus of China's water resources carrying capacity is on evaluation methods and indicator systems, which are widely used in sustainable development and environmental protection [12,13]. But Henan province is concerned, the spatiotemporal differences in water resources carrying capacity are rarely studied. Therefore, this paper firstly makes a systematic analysis of the carrying capacity of water resources in Henan.
province, and defines the subsystem elements, research scope. Then, the time series difference analysis of the overall regional (2014-2017) Henan's water resources carrying capacity was carried out.

2. Materials and methods

2.1. Study area

Henan province (figure 1) is located in the middle and eastern part of China (figure 2) and the middle and lower reaches of the Yellow River, with a total area of about $1.67 \times 10^5 \text{ km}^2$. At the same time, the spatial and temporal distribution of water resources in Henan province is extremely uneven, and most of the precipitation is from June to September every year. Influenced by topography, landform and stratigraphic deposition, the overall distribution characteristics of water resources are greater in the south than in the north, and greater in the mountainous area than in the plain.

![Figure 1. Henan Province.](image1)

![Figure 2. Location map of Henan Province.](image2)

2.2. Construction and data collection

2.2.1. Evaluation index system of water resources carrying capacity. Water resources carrying capacity is a complex system, the level of which is affected by the local water resources environment, economy and society. The carrying capacity of water resources mainly refers to the maximum load that can be borne by water resources for economic and social development on the basis of ecological water use. The basic premise is the sustainable planning and utilization of water resources. Starting from the feasibility of evaluation indexes, on the basis of referring to previous studies and combining with the actual situation of Henan province, 11 indexes were selected from three aspects of water resources environment, economy and society to construct the evaluation index system of water resources carrying capacity in Henan province, as shown in table 1.

| Evaluation Index System | Evaluation Index | Units | K-KDJ |
|--------------------------|------------------|-------|-------|
| Water Resources and Environment Subsystem | Total Water Resources | a hundred million m$^3$ | X1 |
| | Domestic Sewage Discharged | ten thousand m$^3$ | X2 |
| | Water for use | a hundred million m$^3$ | X3 |
| | Green Coverage Area | hectare | X4 |
| | Total Volume of Water Supply | ten thousand m$^3$ | X5 |
| | Annual Precipitation | mm | X6 |
| Economy Subsystem | GDP | a hundred million yuan | X7 |
| | Tertiary Industry | a hundred million yuan | X8 |
| | Per Capita GDP | yuan | X9 |
| Society Subsystem | Natural Growth Rate | % | X10 |
| | Total Water Content | a hundred million m$^3$ | X11 |

2.2.2. Data source and processing. The research data were mainly from Henan statistical yearbook...
In view of the limitation of data availability, part of the data was extracted from Henan water resources bulletin (2017, 2016, 2015, 2014). Basic data processing and water resource carrying capacity index calculation were completed under the support of SPSS 19.0, and the spatial distribution map of water resource carrying capacity was drawn on Arc GIS10.3 platform.

2.3. Methods
In this paper, the principal component analysis method is adopted to conduct linear combination of the original variables and convert them into another group of unrelated variables:

\[
\begin{align*}
    y_1 &= \mu_1 x_1 + \mu_2 x_2 + \mu_3 x_3 + \ldots + \mu_p x_p \\
    y_2 &= \mu_{12} x_1 + \mu_{22} x_2 + \mu_{32} x_3 + \ldots + \mu_{p2} x_p \\
    &\vdots \\
    y_p &= \mu_{1p} x_1 + \mu_{2p} x_2 + \mu_{3p} x_3 + \ldots + \mu_{pp} x_p \\
    \mu_{11}^2 + \mu_{12}^2 + \mu_{13}^2 + \ldots + \mu_{pp}^2 &= 1 (i=1, 2, 3, \ldots, p)
\end{align*}
\]

3. Analysis
The characteristic value and cumulative contribution rate of each principal component can be obtained by the calculation of The SPSS19.0. It can be observed from table 2 that the cumulative contribution rate of the first three factors reaches 88.242%, it has exceeded 85% of the requirement. Therefore, the first three factors were selected as the main components to analyze the water resources carrying capacity of Henan Province.

| Principal Component | Characteristic Value | Contribution rate | Accumulative Contribution |
|---------------------|----------------------|-------------------|--------------------------|
| 1                   | 6.395                | 58.135            | 58.135                   |
| 2                   | 2.158                | 19.614            | 77.749                   |
| 3                   | 1.154                | 10.493            | 88.242                   |

In factor 1, the indicators of Total Water Resources, Domestic Sewage Discharged, Water for use, Green Coverage Area and Total Volume of Water Supply play an important role, which can be interpreted as water resources environmental factors.

In factor 2, GDP and Tertiary Industry account for a large proportion, which we interpret as an economic factor.

In factor 3, Natural Growth Rate and Total Water Content index account for a large proportion, which can be interpreted as water resources social factors. The results of Analysis of Variance show that the cumulative variance contribution rate of the first three principal components is 88.242%. Obviously, these three principal components can explain most of the variation of the evaluation indicators, so they can be regarded as the principal components for evaluating the carrying capacity of water resources. The variance contribution rates of the three principal components are respectively 58.135%, 19.614% and 10.493%, which is the weight of each principal component in the comprehensive evaluation model. On the basis of principal component load analysis, according to the variance contribution rate of each principal component and the load coefficient of each principal component on the main evaluation index, the weight value of each principal component and evaluation index can be determined, and the following comprehensive evaluation model of water resources carrying capacity can be constructed:
\[ F_j = \frac{\sum_{i=1}^{3} w_i F_{ij}}{\sum_{i=1}^{3} w_i} = \frac{w_1 F_{1j} + w_2 F_{2j} + w_3 F_{3j}}{w_1 + w_2 + w_3} = \frac{58.135 F_{1j} + 19.614 F_{2j} + 10.493 F_{3j}}{88.242} \]

Where \( F_j (j=1,2,3,\ldots,17) \) is the comprehensive score of water resources carrying capacity of the jth sample city, \( w_i (i=1,2,3) \) is the weight coefficient corresponding to the ith principal component.

4. Conclusion
Statistical software SPSS19.0 was used to conduct factor analysis on the index data of water resources carrying capacity of 17 cities, and the subsystem and comprehensive total score were obtained (figure 3). According to the overall score of each subsystem in figure 2, the longitudinal comprehensive evaluation comparison can be concluded as follows:

- during the sample period, the overall water resource carrying capacity of Henan province showed a steady rising trend. The cities with good water resource carrying capacity were Zhengzhou, Luoyang, Xinxiang and Nanyang. The cities with better carrying capacity of water resources are: Kaifeng, Pingdingshan, Anyang, Jiaozuo and Xinyang; The carrying capacity of water resources in other cities is general;
- the contribution of each subsystem to the comprehensive carry capacity of water resources increases year by year, among which the contribution of the water resources environment subsystem and the economic subsystem is the largest, and the contribution of the social
subsystem is relatively lasting.

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