2008-2016 Water security status and short plate element screening in Shandong province

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Abstract. In order to explore the applicability of the methods for protecting regional water resources, the water resources safety evaluation index system of Shandong Province was constructed, and the water resources safety relative closeness degree was used to characterize the water resources security situation of Shandong Province from 2008 to 2016; the matrix of water resources safety impact factors of Shandong Province was constructed. The factor analysis method is used to calculate three principal component factors, and the short board elements are identified. The paper concluded by comparing the development trend of water resources security in Shandong from the aspects of vertical (interannual) and horizontal (indicator). The results show that: (1) The water security system of Shandong Province was mildly unsafe in 2009. It was barely safe in 2015 and 2016, and the rest of the year was in an unsafe state. In 2008-2016, the state of water resources security in Shandong Province showed that the situation in the previous period was relatively tight and the later contradictions eased, but the overall security situation was still severe. (2) Factor analysis shows that the lack of water resources and high-intensity development and utilization are the main short-term factors affecting water resources security in Shandong Province.

1. Preface
Water resources safety assessment is the identification and study of the integrity of regional water resources ecosystems and the sustainability of maintaining their health under various risks, thus judging regional water security issues for national and regional security is of great significance. As early as 1992, Falkenmark [1] used the per capita water resources as a measure of water security and analyzed the critical value of water security. Afterwards, many scientists invested in the issue of water security, and many research methods with guiding significance were born. Such as: DPSIR model [2], entropy weight method [3], contact number method [4]. Zhenhua Yang [5] conducted a water resource safety assessment using the SPA-MC coupling model. Junhui Zhao [6] uses Xinjiang as an example to evaluate the development of low carbon economy by using DPSIR model.

Shandong Province lacks water resources. The water resources are unevenly distributed in time. In addition to the high-intensity water resources development, the contradiction between water supply and demand is sharp. This paper identifies the short-term elements of water resources in Shandong by identifying the state of water resources security in Shandong Province, and analyzes the development trend of water resources security in Shandong from the aspects of vertical (interannual) and horizontal (indicants). It is of great significance to optimize the allocation of water resources, improve the utilization of water resources, and promote the economic and social development of Shandong Province.
2. Data sources and research methods

2.1. Data Sources

The data in this paper comes from the website of the National Bureau of Statistics, the 2008-2016 Shandong Water Resources Bulletin and the Shandong Statistical Yearbook [7].

2.2. Research methods

2.2.1. Evaluation Index System of Water Resources Safety

According to the connotation of water resources security, the water security system includes five security subsystems: water supply security, flood control safety, water environment security, water ecological security and social economic security [8]. In view of the representativeness and availability of water resources in Shandong Province in terms of social, economic, natural resources and environmental factors, the water resources safety evaluation index system of Shandong Province was constructed, as shown in Table 1.

2.2.2. Entropy Weight TOPSIS Method

The TOPSIS method combines an ideal solution and a negative ideal solution based on existing data, and then uses these two schemes as a standard to rank other schemes. The ideal solution maximizes the efficiency standard and optimizes the cost standard, while the negative ideal solution maximizes the cost standard and minimizes the benefit standard. Before using the TOPSIS method, it is necessary to give weight to the indicator system. Here, the objectivity method with strong objectivity is selected. The following are specific calculation steps.

2.2.3. Factor analysis method

The factor analysis module of SPSS software [9] was used to establish the water resources safety evaluation index system of Shandong Province. For the correlation between the data of variables, through analysis and calculation, multiple variables are converted into fewer common factors. According to the principle that the common factor cumulative variance contribution rate should be above 85%, the integrated original variable can be divided into type A. Then it identifies the short-term elements of the water resources security system in Shandong Province and analyzes the development trend of water resources security in Shandong.

3. Results and analysis

3.1. Grade evaluation of water resources security

Using the entropy weight method, the weights of water resources safety status evaluation indicators in Shandong Province were obtained and ranked (Table 1). Then through the index analysis method (TOPISIS method), the results of water resources safety status evaluation in Shandong Province are obtained (Figure 1).

Table 1. Weight ranking of evaluation indicators for water resources safety and Scores of three principal component factors affecting water resources security in Shandong province.

| Index                | Weight          | Sort | Principal component F1 | Principal component F2 | Principal component F3 | Index attribute |
|----------------------|-----------------|------|------------------------|------------------------|------------------------|-----------------|
| Surface water        | 0.120122507     | 1    | 0.878                  | 0.421                  | 0.087                  | +               |
| Groundwater          | 0.074488756     | 2    | 0.858                  | 0.465                  | 0.082                  | +               |
| Wastewater treatment rate | 0.072762072 | 3    | 0.856                  | 0.411                  | -0.057                 | +               |
| Daily water supply   | 0.071754019     | 4    | 0.676                  | 0.717                  | -0.06                  | +               |
| Per capita water     | 0.071524533     | 5    | -0.437                 | -0.894                 | 0.047                  | +               |
| Groundwater          | 0.064373566     | 6    | -0.431                 | -0.897                 | 0.036                  | +               |
| Whole society GDP    | 0.064014485     | 7    | -0.857                 | -0.399                 | -0.148                 | +               |
| Total water supply   | 0.063849354     | 8    | -0.893                 | 0.103                  | -0.288                 | +               |
| Per capita GDP       | 0.06309659      | 9    | -0.754                 | -0.442                 | 0.034                  | +               |
| Surface water        | 0.059128652     | 10   | -0.855                 | -0.325                 | 0.169                  | +               |
Table 2. Water resources security rating.

| Extreme Unsafe | Serious Unsafe | Moderate Unsafe | Light Unsafe | On the verge of Unsafe | Barely safe | Primary security | Intermediate security | Good security | High quality security |
|----------------|---------------|-----------------|-------------|----------------------|-------------|-----------------|-----------------------|---------------|-----------------------|
| 0.00-0.09       | 0.10-0.19     | 0.20-0.29       | 0.30-0.39   | 0.40-0.49            | 0.50-0.59   | 0.60-0.69       | 0.70-0.79             | 0.80-0.89     | 0.90-1.00             |

Overall, the water security situation is not optimistic. From 2008 to 2009, the water security status of Shandong Province dropped from insecurity to light unsafe. In the following four years, the water resources security situation improved year by year, but it was still in the unsafe interval. From 2013 to 2015, water security improved significantly and reached a state of reluctance and security; in the next two years, the security status remained almost unchanged, and it was still barely safe.

3.2. Analysis of Short Plate Elements for Water Resources Safety

The SPSS statistical software was used to analyze the relevant raw data of Shandong Province, and then the short-board elements were screened. Before performing factor analysis, it is necessary to analyze the relevant raw data of Shandong Province by KMO and Bartlett test to determine whether it is suitable for factor analysis. The test results are shown in Table 3.
Table 3. KMO and Bartlett test results.

| KMO Sampling Appropriateness Quantity | Bartlett sphericity test |
|---------------------------------------|--------------------------|
| 0.617                                  | Approximate chi square   |
|                                       | Freedom                  |
|                                       | Saliency                 |
|                                       | 173.090                  |
|                                       | 28                       |
|                                       | 0.000                    |

KMO is mainly used to test the partial correlation between variables, which is between 0 and 1. Generally, if it is less than 0.05, it can reject the assumption that variables are independent, and consider that there is a strong correlation between variables, which is suitable for factor analysis.

Table 4. Eigenvalues and cumulative contribution rates of correlation matrices.

| Principal component | Initial eigenvalue | Extracting Square Sum of Load | Square Sum of Rotating Load |
|---------------------|--------------------|--------------------------------|----------------------------|
|                     | Total              | Percentage of variance         | Cumulative %               | Total              | Percentage of variance | Cumulative %               |
| F1                  | 11.033             | 68.956                         | 68.956%                    | 11.033             | 68.956%                | 68.956%                    |
| F2                  | 2.396              | 14.975                         | 83.931%                    | 2.396              | 14.975%                | 83.931%                    |
| F3                  | 1.335              | 8.343                          | 92.274%                    | 1.335              | 8.343%                 | 92.274%                    |

The results in Table 4 show that the characteristic values of the principal components F1, F2, and F3 are 11.033, 2.396, and 1.335, respectively. The eigenvalues of these three principal components are all greater than 1, and their cumulative reaches 92.274%. Therefore, the main components F1, F2, and F3 are taken to analyze the short-term elements of water resources in Shandong Province.

In order to more clearly reflect the importance of each influencing factor to the principal component, Caesar normalization of the factor loading matrix is rotated to obtain an orthogonal transformation matrix. The results of the factor load matrix after rotation are shown in Table 1. Through the different scores of each index in the orthogonal transformation matrix, it can be concluded that the principal component factors F1, F2 and F3 are: water endowment, carrying capacity and development and utilization, socio-economic development status, and application of technology.

The first principal component factor F1 represents the water endowment, carrying capacity and development and utilization of Shandong Province, and its variance contribution rate is 68.956%. The lack of water resources affects its score. According to the change curve of the score: the first principal component factor has large fluctuation, which indicates that the inter-annual variation of water resources in Shandong Province is very obvious, which has an important impact on the water resources security of Shandong Province.

The second principal component factor F2 represents the constraints and impacts of the socio-economic development of Shandong Province on the state of water resources security, with a variance contribution rate of 14.975%. The lower the score, the worse the water security status. Economic development promotes the simultaneous evolution of water resources. At the same time, under the existing scientific and technological conditions, the rapid economic development will inevitably lead to the expansion of water use, resulting in increasing pressure on water resources. Judging from the trend of the second principal component factor F2, it is scores down all the way. If no measures are taken, the economic development and water security status will face threats.

The third major factor, F3, is the application of social technology in water resources and the Strength of social research. The contribution rate of variance is 8.343%. The higher score of the third common factor indicates that the more the society invests in water resources and the more research work, the more helpful it is to solve the problem of water resources security. Factor F3 was at its lowest point in 2013 (mainly due to the reduction in effective irrigated area), followed by an overall upward trend and a significant increase between 2015 and 2016. This shows that this factor has great potential and significant effect in solving water security problems.
4. Conclusions and recommendations
Through the evaluation of the water resources safety in Shandong Province and the analysis of short-term factors, it is concluded that:(1) The state of water resources security in Shandong Province is characterized by the early tension and the relaxation of later contradictions, but the overall security situation is still severe. In 2009, it was mildly unsafe, and 2015 and 2016 were barely safe. The rest of the year was in an unsafe state. (2) The most influential factors of water resources security short-board factors in Shandong Province are the lack of water resources and high-intensity development and utilization, followed by the fragile carrying capacity of water resources, and finally the “high water consumption” under social and economic development.

In view of the current situation of lack of water resources and high intensity development in Shandong. First, we should actively seek alternative water resources while fully utilizing existing water resources. Then strengthen water resources management system and improve provinces and cities. Second, county water use efficiency and perfect water function area limit pollution control index system. Besides, vigorously promote water ecological construction, strengthen water ecological protection, accelerate the implementation of water system ecological comprehensive improvement, improve water resources carrying capacity. Finally, promote economic transformation, transfer or shut down high consumption and high pollution enterprises.

Acknowledgments
This study was financially supported by the Natural Science Foundation of China (NO.41471160).

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