Evaluation of water resources value from the perspective of scarcity of resources (Taking Beijing as an example)

Chaoyi Zhang

Hohai University, Changzhou 213022, China.

zhangcy158@126.com

Abstract

Establishing a fuzzy-grey correlation model, organically combining the scarcity of water resources with the accounting of water resources values, so that the measurement of water resources value is more objective and real, and helps the water market transactions to achieve a good and stable state. The analysis is more reasonable.

Keywords

Water resource value; Fuzzy-grey correlation model; Water value prediction.

1. Introduction

Water resources are the basic natural resources for human beings and all living things to survive and develop. [1] With the development of industry and agriculture, the quality of water environment is deteriorating, the water crisis is intensifying, and water shortage has become a common problem facing the world. China's water shortage is very serious and has been listed by the United Nations as one of the 13 poor countries. The water issue is a major issue in China's economic development in the 21st century. In 2002, the Water Law of the People's Republic of China, which was revised and implemented by the Standing Committee of the National People's Congress of the People's Republic of China, clearly stipulates that planning is required, and comprehensive scientific investigation and investigation and evaluation of water resources must be carried out.

In 2017, the report of the 19th National Congress of the Communist Party of China Once again, it is clearly required to "make the market play a decisive role in resource allocation". Therefore, the research on the value of water resources has become a hot spot in the field of water resources research; it is the core content of water resources economic management.

The study of *the value of water resources* is an important part of water resources management.[2] It is of great significance for rational allocation of water resources, improvement of water environment, promotion of water conservation, and mitigation of water crisis. The scarcity of matter is the basis of economic research. Therefore, this topic combines the scarcity of water resources with the accounting of water resources value, so that the measurement of water resources value is more objective and truer.

The purpose of this project is to use the *fuzzy-grey correlation analysis model* to analyze the constituent factors and changing laws of water resources value from the perspective of scarcity of water resources.[3] Determine the influencing mechanism and action path of each factor, firstly quantify the scarcity of water resources, combine the water scarcity with the price formula, estimate the value of water resources in the perspective of scarcity, and finally the theoretical water price and Compared with the actual water price,[4] it proposes a better water resource allocation management plan, so that the water resources can reach an orderly and harmonious development state in the market configuration.

2. Experiment-Water resource value prediction model

The water resource value system is complex, and it is a system in which multiple factors interact, interact, and interact.[5] The system is influenced by many factors, including natural factors, social factors, and economic systems. In this system, because the relationship between multiple factors is unclear or even impossible to determine accurately, it is difficult to explain such complex systems using conventional mathematical models. Because in complex systems, as the complexity of the system increases, the ability to make it more precise is diminished. In a certain range, complexity and accuracy are inversely related. Therefore, based on the complex and fuzzy system of water resources, based on fuzzy theory and grey theory, a fuzzy-grey correlation composite value model is established to measure the value of water resources.

2.1 Fuzzy comprehensive evaluation of water resources value

Water value factors include factors of the natural, social and economic systems. Natural factors are the decisive factors determining the scarcity of water resources, including total water supply, total agricultural water use, and effective irrigation area. Economic factors play a key role in the value of water resources, including per capita GDP and wastewater treatment. Investment, etc.; social factors play an indispensable role in the study of the scarcity of water resources, including the permanent population at the end of the year, the urban population, and the per capita water consumption.[6]

The fuzzy comprehensive evaluation model of water resources value is as follows：

(1)Determining the factor domain of the evaluation object. $x = (x_1, x_2, x_3, \cdots, x_m)$ ， among $x_1, x_2, x_3, \cdots, x_m$ Representing factors affecting the value of water resources, such as: permanent population at the end of the year, urban population, regional GDP, per capita GDP, total water supply, per capita water supply, total agricultural water use, effective irrigation area, crop planting area, city Daily sewage treatment capacity, etc.

(2)Determining the rating hierarchy$y = (y_1, y_2, y_3, \cdots, y_n)$，In fact, it is a division of the change interval of the object to be evaluated, where y_i represents the *i*th evaluation result and *n* is the total number of results.

(3) Single factor evaluation. Create a fuzzy map from *X* to *Y*:

$$f: X \to F(Y), x_i \to \frac{r_{i1}}{y_1} + \frac{r_{i2}}{y_2} + \cdots \frac{r_{in}}{y_n} (0 \le r_{ij} \le 1, i = 1,2,\cdots,m; j = 1,2,\cdots n) \quad (1)$$

An evaluated object is at a certain factor u_i's presentation is performed by Fuzzy vector, $r_i = (r_{i1}, r_{i2}, r_{i3}, \cdots, r_{im})$，$r_i$ is 'Univariate evaluation matrix'；From f we can get 'Fuzzy relation matrix' $R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{in} \end{bmatrix}$, and *R* is 'Comprehensive evaluation matrix' which is made up by $x_1, x_2, \cdots, x_m$.

(4) Determining the fuzzy weight vector of the evaluation factor。In order to reflect the importance of each factor, each factor *x* hould be assigned a corresponding weight $a_i (i = 1,2,\cdots,m)$，usually a_i is required to satisfy $a_i \ge 0; \sum a_i = 1$, then a_i represents the weight of the *i*th factor，and thus the fuzzy weight matrix $A = (a_1, a_2, a_3, \cdots, a_m)$. The weight value is determined by the "pairwise comparison method". The pairwise comparison method is based on regional characteristics and expert opinions, and compares the importance between any two factors of m factors to obtain the evaluation matrix $W = (w_{ij})_{mm}$， where w_{ij} represents the ratio of the importance of the *i*th factor and *j*th factor can be expressed here as the mean of the expert assignment.

(5) Fuzzy comprehensive evaluation. According to the fuzzy relation matrix R and the weight vector matrix W，the comprehensive evaluation matrix B=W-R is obtained.

2.2 Grey relational analysis of water resources value

For the fuzzy comprehensive evaluation result matrix *B*，gray correlation analysis is performed for each evaluation unit.

(1) Determine the reference series. For the specified *n* reference series

$$X_{0j} = \{X_{0j}(1), X_{0j}(2), \cdots X_{0j}(k), \cdots X_{0j}(n)\} (j = 1,2,\cdots,n) \quad (2)$$

Where j=k，$X_{0j}(k) = 1$；Otherwise $X_{0j}(k) = 0$

(2) Initial value processing. The fuzzy comprehensive evaluation result matrix of each evaluation unit is subjected to initial value processing.

Let all $X_i'(k) = \frac{X_i(k)}{X_i(1)}$， and then get a new initialized sequence, which is used as a comparison sequence. which is

$$X_i' = \{X_i'(1), X_i'(2), \cdots X_i'(k), X_i'(n)\}\ i = 1,2,\cdots,m \tag{3}$$

(3) Calculate correlation coefficient. The difference between each of the compared series and each reference number is calculated by the following formula.

$$\varepsilon_i(k) = \frac{\min_j \min_k |x_0(k) - x_i(k)| + \theta \max_i \max_j |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \theta \max_i \max_j |x_0(k) - x_i(k)|}\ i = 1,2,\cdots,m \tag{4}$$

(4) Determination of the degree of association. Since the degree of association between each comparison sequence and the reference sequence is reflected by n correlation coefficients, the associated information is dispersed, which is not conducive to the overall comparison. Therefore, there is a comparative process of centralized processing of information.

$$z_i = \frac{1}{m}\sum_{k=1}^{m} \varepsilon_i(k)\ i = 1,2,\cdots,m \tag{5}$$

Get$Z = (z_1, z_2, \cdots z_m)$, which is the water quality evaluation vector

2.4 Determination of the comprehensive price of water resources

Let S be the water price vector. Its form is:$S = (P_1, P_2, P_3, \cdots, P_n)^T$, where each $P = \frac{BE}{C} - D$[7], P is the upper limit of the water price that can withstand; B is the maximum water fee bearing index; E is the per capita disposable income; C is the total amount of water; $D$is the cost of water supply; $P_1, P_2, \cdots, P_{m-1}$ are the price of water with equal intervals. From this, the water price vector F is determined:

$$F = Z \times S = (z_1, z_2, \cdots z_m) \times (P_1, P_2, P_3, \cdots, P_n)^T \tag{6}$$

3. Analysis of water resources value

Selected 13 indicators of Beijing from 2007 to 2016 as analysis samples, including permanent population at the end of the year, urban population, regional GDP, per capita GDP, total water supply, per capita water consumption, total agricultural water use, and effective irrigation area, total water use, total wastewater discharge, investment in wastewater treatment projects, crop planting area, and daily sewage treatment capacity. All data are from the National Bureau of Statistics.[8]

3.1 Determination of weights and results of comprehensive evaluation

According to the pairwise comparison method, the objective weights of each index are as shown in Table 1. The larger the value, the higher the importance of representing the value.

Table 1 Objective weight of each indicator

Index	Permanent population at the end of the year	Urban population	Regional GDP	Per capita GDP	Total water supply
Weight	0.1304	0.1151	0.1025	0.0917	0.0828
Index	Per capita water consumption	Total agricultural water use	Effective irrigated area	Total water use	Total wastewater discharge
Weight	0.0753	0.0694	0.0643	0.0599	0.0566
Index	Investment in wasterwater treatment projects	Crop planting area	Daily sewage treatment capacity		
Weight	0.0532	0.0487	0.0501		

After determining the weight, according to the fuzzy mathematics theory, the comprehensive evaluation result matrix B is calculated.

$$B= [0.1062,0.1009,0.1006,0.1042,0.0993,0.1010,0.0949,0.0927,0.0964,0.1038] \quad (7)$$

3.2 Determination of grey correlation

Based on the calculated fuzzy comprehensive evaluation result matrix B，Calculate the correlation coefficient for each evaluation unit, and determine the correlation degree according to the average correlation coefficient of each unit Z.

$$Z= [0.3965,0.3905,0.3905,0.3959,0.3909,0.3939,0.3885,0.3878,0.3932,0.4328] \quad (8)$$

3.3 Determination of theoretical prices

According to the research of relevant scholars, water fee expenditures account for different proportions of disposable income of residents, and the water use psychology and affordability of residents are different.[9] Therefore, the water consumption index of residents will be different. When the water consumption index is 1%, it has little effect on residents' water use; when it is 2%, it has a certain impact and starts to care about water consumption; when it is 3%, it pays more attention to water use and begins to care about the conservation and utilization of water resources; The number is increasing, and residents' awareness of the rational use of water resources is enhanced. Therefore, according to the actual situation of China's national conditions, the water use index of residents is generally between 3% and 5%. According to the specific water use situation in Beijing, this paper selects 3% as the water consumption index of Beijing. Calculate the water price that each year can withstand according to $P = \frac{BE}{C} - D$:

$$P=[6.3693,5.7272,5.1556,4.4896,4.5884,3.8743,3.0012,2.3250,1.9270,1.3589] \quad (9)$$

Therefore, the theoretical price vector S of the water resource can be derived. According to the interval of the difference, it can be concluded:

$$S=[0.9P,0.8P,0.7P,0.6P,0.5P,0.4P,0.3P,0.2P,0.1P,0] \quad (10)$$

Take 2016 as an example，

$$F = Z \times S^T = [0.3965,0.3905,0.3905,0.3959,0.3909,0.3939,0.3885,0.3878,0.3932,0.4328] \times [5.7323,5.0954,4.4585,3.8216,3.1846,2.5477,1.9108,1.2739,0.6369,0]^T = 11.25 \text{ RMB yuan}/m^3 \quad (11)$$

Similarly, the theoretical water price for 2007-2015 can be calculated as shown in Table 2.

Table 2 Theoretical water price calculation result

Year	2016	2015	2014	2013	2012
Per capita disposable income / RMB yuan	52530.38	48457.99	44488.57	40830.04	36468.8
Total water use /(1/10 trillion)m3	178.64	176.77	175.72	173.89	175.54
Water supply cost /10 thousand RMB yuan	2452.45	2496.71	2439.77	2554.53	1644.19
Theoretical price /（RMB yuan·m-3）	11.25	10.12	9.11	7.93	8.11
Year	2011	2010	2009	2008	2007
Per capita disposable income / RMB yuan	32903	29073	26738	24725	21989
Total water use /(1/10 trillion)m3	180.7	189.39	205.79	210.82	216.58
Water supply cost /10 thousand RMB yuan	1588.27	1604.1	1572.86	1591.44	1686.9
Theoretical price /（RMB yuan·m-3）	6.84	5.30	4.11	3.40	2.40

It can be seen from the calculation results in Table 2 that from 2007 to 2016, the water resource price in Beijing increased from 2.40 RMB yuan/m^3 to 11.25 RMB yuan/m^3, which is a significant upward trend; the calculated water fee increased from 1.1% to 2.14%, indicating that the adjustment of water resources prices in Beijing is still in a reasonable scope. People are increasingly aware of the importance of water conservation, and the value of water resources is gradually increasing. People are correct about the value of water resources. Cognition is getting stronger and stronger. At the same time, it also shows that the adjustment of water resources prices in Beijing still has a lot of room for improvement. By adjusting the above water resources prices, it can play a certain role in water conservation.

4. Conclusion

(1) Taking Beijing as an example, in the case of scarce water resources, taking Beijing 2016 as an example, the calculated water resource price is 11.25 RMB yuan/m^3, which is higher than the actual average price of residential water being implemented. 9 RMB yuan / m^3; when the water price is 9 RMB yuan / m^3, water fee accounted for 2.14% of the resident income, still less than the set value of 3%, indicating that although the value of water resources in Beijing has gradually been valued by residents and the government, But still has a lot of room for improvement. By raising the price of water, it will help to increase public awareness of water conservation and improve water use efficiency, thereby alleviating the scarcity of water resources.

(2) Using the fuzzy-grey comprehensive evaluation model of water resources value and water price accounting model to calculate and compare water resource prices, so as to evaluate the value of water resources from the perspective of resource scarcity, and improve the unity of traditional water resources value assessment model. And the subjectivity of weight determination. It not only considers the natural total amount of water resources, but also considers the economic and social attributes of resources. The use of pairwise comparison methods makes the determination of weights more objective and real, changing the artificial influence of traditional methods, thus making the evaluation results more scientific. . Assessing the value of water resources from the perspective of resource scarcity can better introduce the impact of scarcity on the value of water resources, while scarcity is the basis of economic research, so the evaluation of water resources is more objective.

(3) The current water resource price in Beijing is low, and the water price structure is not reasonable. Although the value of water resources has gradually been valued and correctly recognized, the current water price still lacks the measurement of water resource fees and the lack of sewage treatment. As the most important city in China, Beijing, like other cities in the area, has problems of low water use efficiency, deteriorating water environment and increasing water crisis. Therefore, as a benchmark city in China, Beijing should further strengthen the management level of water resources assets. It should make more in-depth use of new science and technology, more comprehensively and accurately assess the value of water resources, strengthen the construction of water conservancy infrastructure, and enhance residents' awareness of water conservation. Provide constructive advice on water conservation and environmental protection processes in other cities.

(4) Limited to the difficulty of obtaining data, this paper only calculates the water price of residents in Beijing. Although considering the agricultural factors, it does not systematically calculate the prices of agricultural, industrial and ecological water. Agricultural, industrial and ecological water use is the most important form of water consumption in China. The calculation should not simply use the fuzzy-gray comprehensive evaluation method and the comprehensive price evaluation method. It should be based on the combination of its own characteristics and influencing factors. Value assessment and measurement.

References

[1] Xia Fan. Comparative study on application of different water quality evaluation methods: a case study of inflow rivers in Danjiangkou reservoir area[J]. Yangtze River, 2017, 48(17): 11-15, 24.

[2] Peng Xiaoming. Evaluation Model of Water Resources Value Under the Condition of Water Shortage and Its Application[J]. Journal of Natural Resources. 2006, 21(4):670-675.
[3] Jian Fuhu. Construction of the Evaluation System of Water Asset Price With Fuzzy Comprehensive Assessment Indexes: Taking Zhangye Prefecture in Heihe River Basin as an Example[J]. Journal of Glaciology and Geocryology, 2016,38(2): 567-572.
[4] Yang Mengchan. Study on Integrated Water Quality Index and Its Application in Water Resources Assets Assessment in Water Resources Assets Assessment in Shenzhen[J]. Journal of Natural Resources, 2018, 33(7):1129-1138.
[5] Shen Dajun. Water Price Theories and Practice[M]. Beijing Science Press, 2001:154-160.
[6] Xia Yuanping. Research Status and Evaluation Methods of Water Resources in China[J]. Southern Farm Machinery, 2018,49(17):11,27.
[7] Jia Yizhen. Research on Fuzzy Evaluation of Water Resources Value in Lanzhou City[J]. Yellow River. 2018, 40(9):68-73.
[8] Jacksons, Finnm, Scheepersk. The Use of Replacement Cost Method to Assess and Manage The Impacts of Water Resource Development on Australian Indigenous Customary Economies[J]. Journal of Environmental Management. 2014,135(4): 100-109.
[9] Zhao Minjuan. Multi-Objective Collaborative Allocation of Water Resources: A Framework Study Based on Full Value[J]. Chinese Journal of Environmental Management, 2018, 10(5)：8-14.
[10] Information on http://www.stats.gov.cn/.